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OPERATIONAL RISK MANAGEMENT AND MILITARY AVIATION SAFETY

THESIS

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Park D. Ashley

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Abstract

The Air Force Class A aviation mishap rate has hovered around 1.5 mishaps per 100,000 flight hours since 1985. Recent attention on Air Force accidents has caused the leadership to seek to reduce its mishap rate. The Army's Class A aviation mishap rate declined after it implemented risk management (RM) principles in 1987. This reduction caught the attention of Air Force leadership who have since stated that the application of operational risk management (ORM) is how the Air Force will reduce, even eliminate, mishaps. With current budget constraints, ORM is considered to be the most cost-effective way the Air Force can reduce its mishap rate.

The purpose of this research was to determine whether the Air Force can expect its mishap rate to significantly decline due to ORM implementation. This determination is based on the relationship between the Army's implementation of RM and its aviation mishap rate. The analysis of the Army's aviation mishap rates and available causal data was performed primarily using discontinuous piecewise linear regression. Results showed that the effect of RM was not reflected in the Army's mishap rates. As a result, the Air Force should not expect its mishap rate to significantly decline due to ORM implementation.

OPERATIONAL RISK MANAGEMENT AND MILITARY AVIATION SAFETY

I. Introduction

Background

Since man has been flying, aircraft accidents have taken lives, destroyed property, and damaged or destroyed aircraft. Between 1990 and 1996 alone Department of Defense (DoD) aviation losses totaled $9.42 billion, 777 lost lives, and 741 destroyed aircraft (Department of Defense, 1997:ES-2). Flying aircraft, particularly military aircraft that could experience the hazard of combat, is an inherently risky endeavor. Thus, continuously improving military flight safety is a high priority for both civilian and military leaders.

In June 1995, Congressman Ike Skelton of Missouri raised concerns over Air Force mishaps. He cited accidents such as the B-52 crash at Fairchild AFB, the T-38 crash in Texas that hit an apartment complex and the infamous F-15 friendly-fire shoot-down of two Army Black Hawk helicopters over Iraq. Skelton proposed that training, flying hours, spare part resources, and high operations tempo were possible factors for these mishaps (Dorr, 1995:8,9).

Whenever an aviation mishap occurs, a safety investigation ensues. All DoD flight mishap investigations take the form of limited-use safety mishap investigation reports. An investigation's "SOLE purpose is prevention of subsequent DoD mishaps" (Department of Defense, 1989). However, corrective actions to prevent mishaps from reoccurring can be costly not only in terms of dollars, but in time and manpower.

Addressing the primary causes of mishaps and taking steps to prevent mishaps due to these causes is the most logical course of action to improve flight safety. Traditional mishap prevention has centered on improving design of aircraft and maintenance inspection techniques. In an increasingly fiscally constrained operating environment, these methods only go so far toward mishap reduction. Other avenues must be sought and applied if the DoD is going to improve its safety record.

A study performed by the Defense Science Board Task Force on Aviation Safety reported that human error was at least a contributing factor in over 70 percent of DoD Class A mishaps (Department of Defense, 1997:31), the primary measure of flight safety. It determined that the practice of risk management (RM) would be the most effective and least costly method of mishap reduction (1997:31). In fact, one of the recommendations that came out of the study was to integrate RM practices throughout all the services (1997:ES-4). In a letter to all the service secretaries, the Deputy Secretary of Defense suggested a goal of "zero aviation fatalities" with the integration of RM as a means to that end (White, 1997).

The concept of RM has been formally applied to Army operations since 1987. Although the Army did see a reduction in its Class A aviation mishap rate after the implementation of RM, whether or not the reduction was due to RM has been inconclusive.

Problem Statement

Although the DoD's Class A mishap rate has dropped considerably over the history of aviation, during no year has it been zero. For the Air Force, there has been no

significant reduction in the Class A mishap rate since the mid-1980's. It has hovered around 1.5 mishaps per 100,000 flying hours. In order to conserve its most important resources, people and war machines, the Air Force is looking for ways to reduce its aviation mishap rate. The Army aviation mishap rate reduction caught the attention of Air Force leadership who have since stated that the application of operational risk management (ORM) is how the Air Force will reduce, even eliminate, mishaps (Department of the Air Force, 1998b). ORM has been applied on an experiential and intuitive basis for many years but it wasn't until 1996 that the Chief of Staff approved implementation of ORM Air Force-wide. With current budget constraints limiting investment in new designs and inspection tools, ORM is viewed to be the most cost-effective way the Air Force can reduce its mishap rate.

Research Question

Can the Air Force expect the mishap rate to significantly decline after ORM implementation? The answer may lie in looking at the relationship between the Army's implementation of RM and its aviation mishap rate.

Investigative Questions

1. What are the major factors that influence military aviation safety?
2. How does the Air Force implementation of ORM compare to the Army's implementation of RM?
3. Was there a significant difference in the Army aircraft mishap rates after the implementation of RM?
    a) If so, was the difference due to the implementation of RM?

b) If there was a significant difference in the mishap rate, how much of an effect was the implementation of RM?

Scope

This research deals specifically with the effect of risk management on the aviation mishap rate as opposed to ground and off-duty mishap rates. Flight-related and aircraft ground mishaps are not considered. Flight mishaps as defined in DODI 6055.7 are the subject at hand. Although the primary focus will be on the Army Class A mishap rate data, Classes B and C mishap data will also be analyzed to see what effect risk management may have had. Although the Navy and Marine Corps have active ORM programs, they, like the Air Force, are in the infancy of implementation. Since the Army is the lead service concerning risk management, this research will predict what effect ORM may have on the Air Force aviation mishap rate based on the effect RM has had on the Army aviation mishap rate. An assumption for this research is that after RM implementation into the Army, aviators incorporated RM practices into their mission planning.

II. Literature Review

Overview

This chapter provides a background of aviation safety and risk management as it relates to the Army and Air Force. Aviation safety factors are first discussed, describing the typical mishap causes and mishap prevention methods. Second, a history of the risk management concept is described. Safety and risk management terms are then defined as they pertain to the Army and Air Force. Finally, Army and Air Force risk management implementation is examined.

Aviation Safety Factors

There are an infinite number of factors that can affect the safety of any given flight. It is the intention here, however, to identify the major factors recognized by the aviation community as having a significant, proven impact on aviation safety. The discussion will take two related paths. First, those factors typically found causal to a mishap will be described. Second, the prevailing mishap prevention factors will be addressed.

Mishap Cause Factors. According to DODI 6055.7, the four flight mishap cause classifications are human factor, material failure, environment, and other (Department of Defense, 1989). These factors are depicted in Figure 1. The instruction, however, does not define those terms. The Army uses similar terms that parallel those of the DoD instruction. The Army replaces the human factor term with human error, material failure with materiel factors, and does not have an "other" category (Department of the Army, 1999a). The Air Force uses the categories of people, parts, paper, and other (Department

of the Air Force, 1998c:64). For the purposes of this research, the DoD terms will be used. Another term that has received some attention as a viable mishap cause factor the last few years is operational tempo.

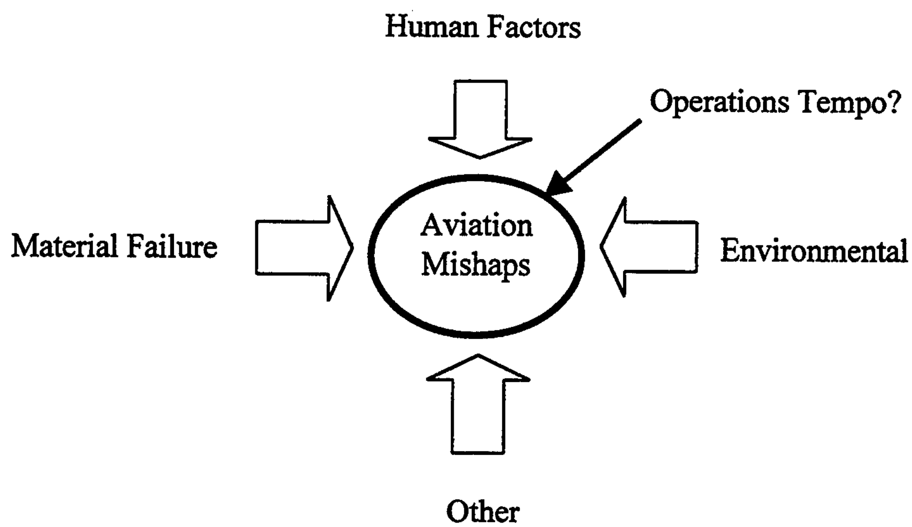


Figure 1. Aviation Mishap Cause Factors

Human Factors. "Human factors in aviation safety concerns itself with the study of human capabilities, limitations, and behaviors and the integration of that knowledge into a system design with the goals of enhancing safety and allowing for more efficient operations" (The Southern California Safety Institute, 1999). Human factors refers to how man and machine interact and is taken into consideration when designing products. A related term is human error. The Army defines human error as "human performance that deviated from that required by the operational standards or situation (Department of the Army, 1999a). The Air Force uses various terms to describe people-caused mishaps: accepted risk, anthropometry, background, complacency, discipline, drugs-medicine, judgment, pathological, perceptions, physiological, preparation, proficiency and psychological (Department of the Air Force, 1998c:226). Mishaps

attributed to human factors are often deemed to be caused by human error. Since human error is at least a contributing factor in the majority of aviation mishaps, it follows that much literature exists describing why human errors occur. Specifically, research has shown that pilot inexperience, spatial disorientation, and poor judgement are major contributors to human error accidents.

Pilot inexperience as a mishap cause factor has been the subject of some study. The Air Force's Tactical Air Command Class A mishap data from 1 January 1979 to 31 December 1983 revealed that 50 percent of operator caused mishaps involved a pilot with fewer than 18 months and 300 hours in the mishap aircraft (McGraw, 1987:5,6). Subsequent changes to the flying syllabus focused on preventing inexperienced pilot mishaps. A review of the same data from 1 January 1984 to 31 December 1986 showed a marked decrease in the percentage of mishaps involving inexperienced pilots. Similarly, Borowsky showed that more experienced Naval pilots had a lower mishap rate than those pilots with less experience. Experience was measured in terms of total flying hours and flying hours by type of aircraft (Borowsky, 1986:ii).

Spatial disorientation is also a common cause of flight mishaps and significant research has been done in that area over the years. Also called pilot vertigo, spatial disorientation occurs when the pilot has an orientational illusion in flight. That is, he believes he is in a particular "position, attitude, or motion relative to the plane of the earth's surface" when in fact he is not (Gillingham, 1986:81). Studies of military aviation show that the percent of mishaps in the Army (7.11 percent) and Navy (6.75 percent) where spatial disorientation was either the cause or a factor are consistent with that of the Air Force. Studies during the periods 1954-1956, 1964-1967, 1958-1968,

1968-1972 and in 1979 revealed that the percentage of Air Force mishaps due to spatial disorientation ranged from 4 to 9.6. The data from 1976 to 1997 reveal that average spatial disorientation Class A mishap rate for fighter aircraft per 100,000 flying hours was .39 (or 5.3 percent) of all fighter Class A mishaps during that time frame (Air Force Safety Center, 1999). The general aviation sector has also suffered from spatial disorientation problems but not as much as the military. As of 1979, only 2.4 percent of general aviation mishaps were due to spatial disorientation (1986:83,84).

The FAA has long recognized the impact human error contributes toward causing mishaps, particularly those causes resulting from poor judgement due to a faulty decision-making process. As a result, in 1987, the FAA published a series of aircrew training manuals entitled Aeronautical Decision Making (ADM). In <u>Aeronautical Decision Making for Commercial Pilots</u>, Jensen and Adrion cite four building blocks that a pilot must have for aviation safety and effectiveness: knowledge, skill, experience, and judgement. Basic knowledge and skills are acquired through training courses, whereas judgement is based on both experience and training (Jensen and Adrion, 1988:1). The Bell Jet Ranger helicopter, used extensively in commercial aviation, saw a significant reduction in human error-related accidents as a result of its crewmembers using the ADM training materials (Adams, 1992:3). The Air Force and Navy also saw significant reductions in human error related accidents (Adams, 1992:4) through use of the materials. It can therefore be said that increased training, particularly in the decision making process, can have a positive effect on human error related mishaps.

<u>Material Failure</u>. The second leading cause of aviation mishaps is material failure. Since humans make aircraft materials, the materials will eventually fail.

Ultimately then, material failure can be traced to a human cause. The point of discussing material failure, however, is to describe immediate reasons for the failure. The Army defines materiel factors as "when materiel elements become inadequate or counter-productive to the operation of the vehicle/equipment/system" (Department of the Army, 1999a). The Air Force uses various terms to describe mishaps due to parts: acquisition, attrition, design, faulty-part, modification, unauthorized modification, and other (Department of the Air Force, 1998c:226-227). General causes of material failure include design not adequate for the load, poor manufacturing process, and material wear out. Material wear out is often due to corrosion or, in the case of aircraft engines, thermal stress.

Environmental. Although not as common a mishap cause as human error or material failure, the environment can have a significant effect on aviation safety. The Army identifies environmental factors as those conditions that affect human or material performance. These conditions may include weather, animals, and electromagnetic environmental effects (E3). E3 result from high intensity radio transmissions and can cause aircraft instruments to malfunction (Department of the Army, 1999a).

Other. As stated earlier, the Army does not have an "other" category but the Air Force does. The Air Force includes animals, manning, other (new reason), unknown, and weather in this category (Department of the Air Force, 1998c:227). The Air Force does not have on "environmental" category but animals and weather would correspond to the Army's environmental category.

Operations Tempo. Operations tempo has been suggested as having an adverse affect on the mishap rate. A study performed by the Air Force in 1994 found no

direct correlation between the two (General Accounting Office, 1996:2). A year later, however, the Air Force Chief of Staff commissioned four retired flag officers, a Blue Ribbon Panel, to examine the Air Force safety program. The Panel did not define the term "operational tempo" or express measures of how it is determined. Nevertheless, it determined that at least six factors within the control of the Air Force contributed to increased operations tempo and presented an aviation safety risk: organizational changes; an unwritten, implicit masters degree requirement; personnel policies; stress at the operational level due to frequent deployments; two level maintenance implementation; support equipment shortages (Department of the Air Force, 1995:19,20).

Mishap Prevention Factors. For every mishap, there is a possible way that it could have been prevented. This section considers four major areas of mishap prevention as described in the literature: leadership, mishap investigation, advancement in technology, and human factor programs. Figure 2 depicts these factors.

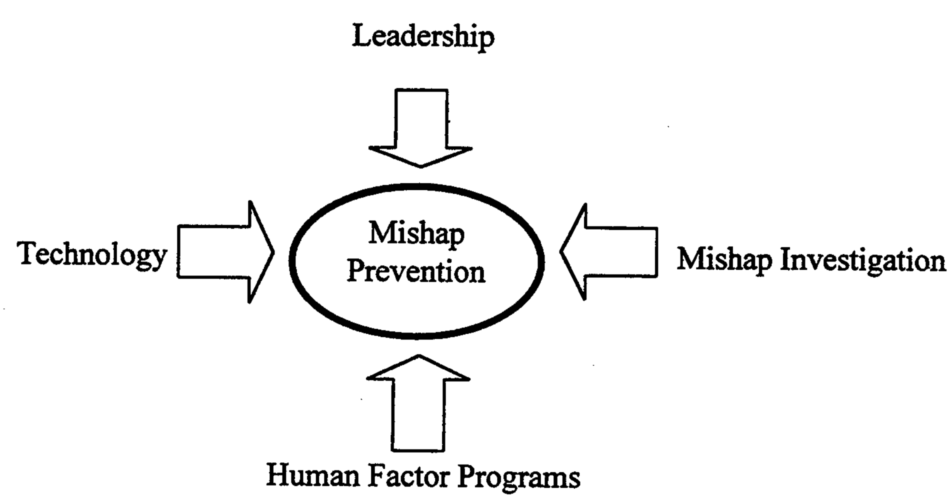


Figure 2. Aviation Mishap Prevention Factors

Leadership. According to the Defense Science Board, "leadership is the single most important factor affecting aviation safety; Commanders at every level must be personally involved" (Department of Defense, 1997:9). It would be beyond the scope of this literature review to pursue a discourse on the Army and Air Force philosophies on leadership. One can assume that there is no difference between what the Army and the Air Force think makes a good military leader. The more appropriate discussion is the emphasis the two services place on aviation safety based on where that responsibility rests in the chain of command.

Army. All aviation personnel have responsibility for mishap prevention but the Army identifies specific positions whose occupants have explicit responsibility for aviation safety. The Secretary of the Army and his advisor, the Assistant Secretary of the Army for Installations, Logistics, and Environment, have responsibility at the Headquarters level. The commander of the Army Safety Center oversees the Army Safety Program and the Director of Army Safety is in charge of the Aviation Accident Prevention Program. Commanders at all levels are responsible for aviation safety under their command. Advising the commander on safety issues is the unit aviation safety officer, the flight surgeon, and the aviation maintenance officer who is responsible for an aircraft preventive maintenance program. The aviator is at the core of aviation accident prevention. At the installation and major command (MACOM) levels, the command safety director is responsible for the management of the command safety program and advises the MACOM commander on aviation safety issues (Department of the Army, 1999b).

Air Force. Like the Army, the Air Force has designated positions and organizations responsible for safety as described in Air Force Policy Directive 91-2. The Air Force Chief of Safety sets safety policy and guidance. The Assistant Secretary of the Air Force for Manpower, Reserve Affairs, Installations, and Environment oversees occupational safety and health policy issues. Commanders must provide a safe working environment by ensuring a mishap prevention program is in place. The safety focus of the commander is the prevention of mishaps both on and off duty and incorporating safety principles to accomplish the mission. All Air Force personnel are responsible for safety by identifying and reporting hazards up the chain of command. Safety staffs at various levels manage the commander's mishap prevention program. This includes the safety office at wing level and the flight safety officer at the flying unit level. The Air Force Safety Center has a wide range of responsibilities including mishap investigation, data storage, tracking corrective actions, and evaluating unit safety programs (Department of the Air Force 1993:2,3). Table 1 summarizes the Army-Air Force leadership comparison.

Table 1. Army and Air Force Safety Responsibilities

Level	Army	Air Force
Headquarters	Secretary of the Army Assistant Secretary of the Army for Installations, Logistics and Environment	Assistant Secretary of the Air Force for Manpower, Reserve Affairs, Installations, and Environment
Safety Center	Director of Army Safety	Air Force Chief of Safety
Major Command	Safety Director	Safety Staffs
Unit	Commanders Aviation Safety Officers Individuals	Commanders Flight Safety Officers Individuals

The Air Force has long realized the importance of the commander's role in aviation safety. In 1987, the Tactical Air Command (TAC) published the Commander's Guide for the Prevention of TAC Fighter Mishaps. A review of mishaps within the command revealed that supervisory error was causal or contributed to 35% of the mishaps between January 1980 and December 1985 (McGraw, 1987:1). The guide addresses flying safety issues new squadron and wing commanders will face when they begin their duties. It specifically addresses the fact that a burden of responsibility for the safety and welfare of those under his command is placed upon him. As then TAC commander General Russ stated, the commander is not "one of the boys" anymore, he is "they" (1987:3). He is the leader and must lead by example in all aspects of life. The guide emphasizes that new commanders study and learn from the mistakes of previous commanders. It also makes clear that the principles and issues addressed are not exclusive to the fighter community but have application in other major commands and the nonfighter aircraft community.

Mishap Investigation. Aircraft mishap investigation has been performed ever since the Wright brothers suffered the crash of their aircraft at Fort Meyer, VA in 1909. It has long been noted within the aviation community that accurate and timely mishap investigations can help prevent similar future mishaps. Over the years, the most effective way to prevent mishaps has been through the mishap investigation and reporting process. Both in civil and military aviation, a safety board convenes to find out what caused a mishap and why and disseminates that information to help prevent similar mishaps. The information goes to aircraft design and acquisition personnel who can then incorporate modifications and safety features into the aircraft. The information also goes

out to current users of the aircraft so that they can make any necessary changes to their procedures.

In civilian aviation, the Federal Aviation Administration (FAA) oversees the commercial and general aviation activities. When mishaps occur, however, the National Transportation Safety Board, an agency independent from the FAA, investigates to determine the cause and provides recommendations to the FAA for corrective action. Since "public safety is the first priority in civil aviation," this independence has worked well in terms of mishap rate reduction (Department of the Air Force, 1995:6).

In the military, each service has its own process for mishap investigation. Studies have been done to determine whether an independent investigative board should be established within DoD. One of the congressional taskings for the Defense Science Board (DSB) was to "determine the need/value of a joint program to require a standardized process for reporting and assessing the causes of accidents" (Department of Defense, 1997:4). The DSB found that each service had its own appropriate process for investigating, reporting, and assessing mishap causes. Although each service organized and administered investigations differently, each service incorporated basic mishap investigation principles adequately and therefore there would be no added value or need for a joint program (1997:16,17). In its study of the same issue, the Blue Ribbon Panel concluded that since the first priority for the military is combat efficiency, it would not be in the military's best interest to have a separate investigative arm (Department of the Air Force, 1995:6,7).

Advancement in Technology. In the early days of aviation, advancement in technology made major contributions to reducing the mishap rate. As aircraft and their

components have become more reliable, the proportion of mishaps due to poor design or manufacture has decreased while the human error proportion has increased (Driskell and Adams, 1992:3). Nevertheless, technology continues to advance, opening new opportunities to help further reduce the proportion of mishaps due to aircraft failure. In its report, the DSB recommended that the DoD provide funding for high priority flight safety equipment as well as for research, design, development, test, and deployment of new equipment. Furthermore, the DoD should use information technology to develop a joint database of flight data recorder performance and maintenance information. This shared resource could help prevent accidents through lessons learned from each of the services (Department of Defense, 1997:ES-4,5).

Human Factors Programs. Since human error is the leading contributing factor to the majority of DoD aviation mishaps, the service leaders have increased emphasis on programs that aim to minimize human error. Two such programs are crew resource management (CRM) and risk management (RM).

Crew Resource Management. The definition of CRM is "the effective utilization of all available resources – equipment and people – to achieve safe, efficient flight operations" (Driskell, 1992:8). Although military and commercial efforts to heighten safety emphasis through CRM have been ongoing since the 1970s, a CRM training program was not established in the Air Force until 1994. In its investigation, the Blue Ribbon Panel found that CRM has been beneficial to the multi-member cockpits, but its impact in the single seat fighter environment, where most of the Class A mishaps occur, is unclear (Department of the Air Force, 1995:14).

Risk Management. "Risk management is the process of identifying, assessing, and controlling risks arising from operational factors and making decisions that balance risk costs with mission benefits" (Department of the Army, 1998a:1-1). It is a tool for the military leader to use to minimize risks and maximize mission accomplishment. Although the military has practiced managing risks for years, it has done so based on intuition and experience (Department of the Air Force, 1998:4). While the concept of managing risks is not new to the military, RM formalizes that process. The DSB recommended that the services make full use of risk management practices as they provide the least costly means of reducing the mishap rates (Department of Defense, 1997:31,32).

Summary. This section described the aviation safety factors pertinent to the research. It presented both mishap cause and mishap prevention factors as found in a review of the literature and described how those factors related to Army and Air Force aviation safety. The mishap cause factors were: human factors, material failure, environmental, and other. The mishap prevention factors were: leadership, mishap investigation, technological advances, and human factor programs. Two human factor programs, CRM and RM, were discussed but remainder of this literature review focuses on risk management history, defines terms, and compares the Army and Air Force implementation of risk management.

Risk Management History

The roots of risk management are embedded in the science of uncertainty: probability. The 17th century French mathematicians, Blaise Pascal and Pierre De

Fermat, are considered the founders of the study of probability (Barnett, 1996:363). Since risk is the probability of a loss, risk management has been practiced in several industries that involve high risk.

Insurance. "The risk at any given time equals the difference between the reserve and the face of the policy" (Neilson, 1958). The insurance industry uses risk management concepts to evaluate whether to offer insurance for someone, and if so, what it will cost the insured. The higher the risk to the company, the higher the cost will be for the insured.

Transportation. The transportation industry uses risk management principles to determine routes when hauling hazardous materials. The goal is to transport hazardous materials as quickly and as safely as possible in order to minimize the risk of exposure to the environment. Factors considered include type and quantity of material, mode of transport, starting point, destination, and population density. Models have been developed that assign weight to the various factors to help decide the route (Helander, 1997:216-226).

Government. The National Aeronautics and Space Administration (NASA) has integrated risk management into their strategic planning. Historically, NASA has used reliability engineering principles to curb risks. Ebling defines reliability engineering.

> The overall objective of reliability engineering is to ensure that the final product will be both economically reliable and reliably safe....Reliably safe requires designing sufficient reliability into the product to ensure that the probability of accidents, injury, or death resulting from a product failure is within an acceptable limit. (Ebling, 1997:429-430)

RM is a decision-making process based on a cost-benefit analysis of known hazards and desired objectives. Reliability engineering, however, is an engineering process based on

the probability of design failure. An RM decision-maker should take into account any reliability information available to make the best decision. While not minimizing reliability engineering techniques, NASA is now focusing efforts on managing the risks of systems interaction. NASA's motivation for mission success stems from the fact that, like the military, its budget is decreasing yet more missions are demanded (Lalli, 1996:355). NASA must determine ways of ensuring reliable missions. The answer is through identifying the hazards and mitigating the risks associated with those hazards, risk management.

The background of risk management has been presented, but before discussing the specifics of RM in the Army and Air Force, some terms need to be defined.

Definitions

Risk. Since this discussion regards both the Army and Air Force, it is important to define the terminology that will be used throughout. At the heart of military aviation mishap reduction and risk management is the term risk. Webster's dictionary defines risk as a "hazard; danger; peril; exposure to loss, injury, disadvantage, or destruction" (Neilson, 1958). The Army defines risk as the "chance of hazard or bad consequences; the probability of exposure to chance of injury or loss from a hazard; risk level is expressed in terms of hazard probability and severity" (Department of the Army, 1998a). The Air Force defines risk as "an expression of consequences in terms of the probability of an event occurring, the severity of the event and the exposure of personnel or resources to potential loss or harm" (Department of the Air Force, 1998a:37). Both the Army and Air Force emphasize the risk elements of probability, severity, and exposure. Despite

minor wording differences, there is no significant difference in definitions of risk between the services. All three definitions are in general agreement.

Risk Management. Although there is minimal DoD-level risk management guidance for the services, Joint Pub 3-0, Doctrine for Joint Operations and Joint Pub 5-0, Doctrine for Planning Joint Operations, do allude to the practice of risk management principles. Since each service is responsible for its own safety program and safety and risk are closely related, each service has developed its own guidelines and instructions for governing its risk management programs. The Army uses the term risk management (RM) and defines it as "the process of identifying, assessing, and controlling risks arising from operational factors and making decisions that balance risk cost with mission benefits" (Department of the Army, 1998a:G-3). The Air Force uses the term operational risk management (ORM) and defines it as "a logic-based, common sense approach to making calculated decisions on human, materiel, and environmental factors before, during and after Air Force mission activities and operations" (Department of the Air Force, 1997:1). The term used in this paper (RM vs. ORM) depends on which service is under discussion. There is essentially no difference between these definitions in that they both state that risk management is a decision making process.

RM Principles. The Army's RM principles are 1) accept no unnecessary risks, 2) make risk decisions at the appropriate level to establish clear accountability, and 3) accept risk when benefits outweigh the costs (Department of the Army, 1998:1-3). The Air Force adds a fourth principle: integrate ORM into Air Force doctrine and planning at all levels (Department of the Air Force, 1998a:6).

RM Process. The Army's RM process consists of five steps: 1) identify hazards, 2) assess hazards to determine risks, 3) develop controls and make risk decision, 4) implement controls, 5) supervise and evaluate (Department of the Army, 1998a:2-0). The only difference between the Army and Air Force risk management process is that the Air Force splits the Army's third step into two steps. Consequently, the Army uses a five-step process and the Air Force uses a six-step process.

DODI 6055.7 defines the following flight mishap terms:

Flight and Flight-Related Mishap. An aircraft flight or flight-related mishap occurs when intent to fly exists. Specifically, a flight mishap occurs when "there is reportable damage to the aircraft itself." A flight-related mishap occurs when there is "no reportable damage to the aircraft itself, but the mishap involves fatality, injury...or other property damage." Until 1983, the Army flight mishap rate was calculated based on both flight and flight-related mishaps. Beginning in 1984, the Army flight mishap rate was calculated based on flight mishaps only.

Intent for Flight. Intent for flight is assumed during the time from takeoff brake release or power application until landing is completed.

Mishap Categories. Mishaps are categorized according to their severity in terms of dollar value of damage and personal injury. A Class A mishap involves over $1 million in property damage, a destroyed aircraft, or loss of life or permanent total disability. A Class B mishap involves over $200,000 but less than $1,000,000 in property damage or permanent partial disability or when five or more personnel are inpatient hospitalized. A Class C mishap involves over $10,000 but less than $200,000 in property

damage or injury causing loss of time from work beyond the day or shift upon which it occurred.

Mishap Rate. The mishap rate is the number of mishaps per 100,000 flight hours.

Risk Management Implementation

A hypothesis of this research is that the Air Force implementation of ORM is significantly different from the Army's implementation of RM. If this is not true, and the Army aviation mishap rate saw a significant reduction due to RM application, then the Air Force may also see a similar reduction in its mishap rate. Implementation of RM into the Army and of ORM into the Air Force was evaluated using three criteria: published directives, responsibility, and training.

Army. The Army officially began the implementation of RM in 1987. AR 385-10, The Army Safety Program, addressed the integration of risk management throughout the Army: "Decision-makers at every level will employ risk management approaches to effectively preclude unacceptable risk to the safety of personnel and property" (Department of the Army, 1999c). According to Stearns, RM was "successfully integrated into the Army's training and operational process" (Stearns, 1990:32).

In 1997, the Secretary of the Army formally established responsibilities for the full integration of RM (Department of the Army, 1998b). At first RM was a safety officer function applicable to the training and operational areas, particularly the aviation community (Department of the Army, 1998a:iii). However, FM 100-14, Risk Management, the Army manual for the application of RM, clearly places the responsibility of RM integration on commanders, leaders, staffs, and individuals. Further

RM integration guidance stipulates that "HQDA (Headquarters, Department of the Army) Principal Officials and MACOM (major command) commanders are designated integrating agents" (Army Safety Center, 1999a).

Risk management was incorporated into the Army's material acquisition process in the late 1980's and into its doctrine, training, and professional military education in the early 1990's (Van Aalten, 1999). The Army attributes, in part, its recent aviation mishap reduction success to the aviation safety officers who applied RM techniques (Army Safety Center, 1999b). However, in the Army's recent integration effort, it has recognized the need for a cadre of trained safety personnel skilled in being able to broadly apply RM techniques (Army Safety Center, 1999b). The goal is to integrate RM practice and training for all individuals both on- and off- duty in order that it become second nature and embedded in the Army culture (Department of the Army, 1998a:iii).

Air Force. On 2 Sep 96, the Air Force Chief of Staff ordered the implementation of ORM to begin. Full implementation through computer-based awareness training on an individual level was completed 1 Oct 98. Thus, Air Force ORM is in its infancy. AFI 91-213, "Operational Risk Management (ORM) Program," established the requirement to incorporate ORM programs throughout the Air Force and outlines their description, management, and development. Each major command is responsible for developing and implementing its own ORM programs. AFPAM 91-215, "Operational Risk Management (ORM) Guidelines and Tools," describes how to integrate and execute the ORM process.

While it is the responsibility of the major commands to develop and implement its own programs, it is the responsibility of commanders at all levels, supervisors, and

individuals to execute the practice of ORM both on- and off- duty (Department of the Air Force, 1998a:4).

While the Army's initial emphasis was to apply RM through the commanders in the operational and training areas, from the start the Air Force took a more holistic approach with application in all areas. The emphasis in the Air Force has been the implementation of ORM through training and education from the top down. There are four levels of training: awareness, mission and workplace specific, supervisor, and ORM advisor. The Air Force provides training to a cadre of major command safety professionals who, in turn, provide training and guidance at the wing levels. ORM has also begun to be taught in the initial stages of an individual's career beginning with basic military training and officer commissioning sources. It is also taught at the various technical schools and professional military education courses throughout one's career (Department of the Air Force, 1997:4-5).

While the Army and Air Force have taken different tracks to the same goal, it does not appear that their risk management implementations have been significantly different. Both services have established a trained cadre of risk management personnel and are integrating the philosophy at all levels for all individuals to apply both on- and off- duty. It is likely that the Air Force learned much from the Army before launching its ORM program.

<u>Summary</u>. This section examined the implementation of RM in the Army and ORM in the Air Force using three criteria: published directives, responsibility, and training. The Army began implementation in 1987 and focused its implementation efforts in the acquisition, operational, and training areas. It later expanded RM

implementation into its doctrine and educational process. The Air Force began implementation in 1996 and completed awareness training in 1998. From its inception, ORM was implemented into all areas. While RM implementation has progressed at different rates for each service, both the Army and Air Force are taking similar steps to arrive at the same goal: mishap prevention, both on- and off- duty. Thus, the implementation procedures do not appear to be significantly different.

Summary and Conclusions

This chapter provided a review of the aviation safety factors as revealed in the literature, including those related to mishap cause and prevention. A history of risk management was discussed as well as the definitions of risk management terms. How the Army and Air Force have implemented risk management concepts into their operations was examined. Based on this review, it appears that the focus of aviation mishap reduction is centered on the application of risk management. The Army has put much effort into reducing its mishaps through RM techniques and its mishap rate has declined. Was this decline due to RM application? The next chapter will describe how the available data was analyzed and may help answer this question.

III. Methodology, Results, and Analysis

Overview

This chapter is the heart of the research project. It describes the data collected and reviews the possible sources of time series invalidity. The primary focus of this chapter, however, is a presentation of the methodology, results, and analysis that address the investigative questions posed in Chapter I.

Data Collection and Description

To conduct the analysis, aviation safety data was acquired from both the Army and Air Force.

Army. The Army Safety Center (ASC) provided Class A and Class A-C data (rates and numbers of mishaps) from 1973 to 1998 but the individual Class B and C data were not available. Additionally, Class A, B, and C data by aircraft type from 1988-1998 were provided. By extracting the Class A data out of the Class A-C data, a separate category of Class B-C mishaps was constructed. The ASC also provided flight mishap causal data for fiscal years 1990 to 1998. The data include aircraft type, class, and cause category (human error, materiel failure, and environmental) for each year. Since Class A-C mishap rates include events in the B-C category, only Class A and Class B-C category mishap rates were analyzed. Table 2 summarizes the Army data collected. The mishap rates prior to and including 1983 were computed based on flight and flight-related mishaps. Since 1984, however, rates have been computed based on flight mishaps only. The mishap rate based on flight and flight-related mishaps will be higher than if

Table 2. Army Data Summary

FY	Class A Rate	Class A-C Rate	By MTDS	# of Mishaps	Causes
73-87	YES	YES	NO	YES (Class A only)	NO
88-98	YES	YES	YES	YES	NO
90-98	YES	YES	YES	YES	YES

flight mishaps only are considered in the calculation. This confound is addressed later in this chapter.

Since the Army implemented RM in 1987, the data cover a period before and after implementation although causal information dates back only to 1990. The Army data is presented in Appendix A.

Air Force. The Air Force Safety Center provided flight mishap causal data for fiscal years 1993 to 1998. Since the Air Force completed initial ORM implementation in 1998, the data only cover the period before implementation. The data include aircraft type, accountable category, responsible agent, and reason for each year. As described in Chapter II, the reasons are further broken down into people, parts, paper, and other categories. The people category is of interest to this research and corresponds to the Army's human error category. Class A data from 1947-1997 and Class A and B data by aircraft type from 1972-1998 were obtained from the Air Force Safety Center World Wide Web site. The Air Force data and related information are presented in Appendix B.

Sources of Time Series Invalidity

This research treats the mishap rate as the response variable and risk management as the treatment. Given that time series data is evaluated in this research, care must be taken to assess the effect of threats to internal and external validity. Campbell and

Stanley describe various types of experimental designs and identify the associated sources of threat to their internal and external validity (Campbell, 1963). A more rigorous discussion of the threats is found in Cooper and Emory (1995:357-361). This section specifically identifies the threats to the evaluation of aviation mishap rate data as it relates to the implementation of risk management in the Army and Air Force.

Internal Validity. Campbell and Stanley identify eight potential threats to internal validity for a time series design study (Campbell, 1963:40). Only the failure to control history, however, is considered a strong threat relative to the other seven sources.

History. For a time series study, history is the single largest threat to internal validity. It is possible that factors other than that being tested caused a change to occur. As stated in Chapter II, there are numerous reasons for an aviation mishap and at least as many ways of prevention. Four major aviation mishap prevention factors were identified in Chapter II: leadership, mishap investigation, advancement in technology, and crew resource management, a human factors program. Risk management, also a human factors program, is only one way of preventing mishaps and it may or may not have been a factor in any significant change in the Army's aviation mishap rate in recent years. These mishap prevention factors are together considered responsible for any trend in the mishap rate before 1987. If there were any changes in the trend after 1987, it would first have to be attributed to any identifiable changes in those factors if they were contemporaneous with RM (1986-1988). After that, any change left over can be attributed to the treatment of RM. A brief historical overview of each mishap prevention factor was conducted to examine any confounds that may exist.

Leadership History. The Army recognizes that aviation safety can be improved through proper leadership. In 1984 the Director of Army Safety became a general officer position to report directly to the Army Chief of Staff (Hicks, 1999). Additionally, the Army has conducted much research to continuously improve the leadership development of its members. In 1986, the Noncommissioned Officer Professional Development Study was conducted. In 1987, the Army Chief of Staff directed that the Deputy Commandant, Command and General Staff College (CGSC) conduct a comprehensive leader development study. The Leader Development Support System, in use today, was established in 1989 as a direct result of the CGSC study. In 1991 the Leader Development Investment Strategy study was performed to address issues facing the rapidly downsizing Army (Department of the Army, 1999d). Currently, the Army Safety Center is leading the Aviation Safety Investment Strategy. This effort is examining mishaps by aircraft type and is developing strategies to reduce mishaps (Hicks, 1999).

Mishap Investigation History. Mishap investigation has also been considered to improve aviation safety. In its continuing effort to prevent aircrew injuries, the Army's Aeromedical Research Laboratory (AARL) established the Aviation Life Support Equipment Retrieval Program (ALSERP) in 1972. Members from the AARL often participate in mishap investigations. By retrieving and evaluating equipment involved in mishaps, the AARL provides critical design criteria for improved life support equipment. Specifically, three types of helmets have been fielded since 1972: the SPH-4 Mod (1978), the SPH-4B (1991), and the HGU-56/P (1995). "Each of these helmets incorporate incremental improvements designed or intended to reduce or prevent injury"

(Voisine, 1996:3). Flight data recorders are useful in mishap investigation because their data can be downloaded into a computer and the mission can be "flown" again. Investigators can then determine what the aircraft was doing before and during the mishap sequence. In 1986, the UH-60A Black Hawk was the first Army aircraft have flight data recorders installed (Army Weaponry and Equipment, 1986:387). Flight data recorder installation is ongoing today (Hicks, 1999). Changes in the composition of mishap investigation teams have also taken place. In the late 1980's the Army Safety Center representation on mishap investigations dropped from three to two. The civilian safety specialist was removed due to resource constraints (Hicks, 1999). In the mid-1990's, the ASC information requirement for Class C mishap reporting was reduced to the Abbreviated Aviation Accident Report. This policy is currently being re-evaluated to ensure that all necessary data is archived (Hicks, 1999).

Technology Advancement History. Technology advancements have made Army aviation relatively safer over the years. Fielding new or modified aircraft with improved safety features might contribute toward mishap reduction. In 1984 the first CH-47D Chinook was delivered. It is an upgrade from the A, B, and C models (Army Weaponry and Equipment, 1986:392). The UH-60A Black Hawk helicopter was fielded between 1978 and 1989. The aircraft include crashworthy armored crew seats (1986:387). In 1986 the first AH-64A Apache attack helicopter was delivered to Ft. Hood, TX (1986:387). Also in 1986, the first modernized AH-1S Cobra was delivered through the Cobra Fleet Life Extension Program. One if the program's key features was a new drive shaft designed to improve safety (1986:389). In 1990, the H-6-530 aircraft

began a no tail rotor (Notar) system modification. One effect of removing the tail rotor was improved safety margins due to weight and power savings (Brown, 1990:44-45).

CRM History. As stated in Chapter II, research regarding the human factor program of crew resource management (CRM) has been ongoing since the 1970s. The Army, recognizing the need to address crew errors, first introduced a 6-8 hour block of CRM-type training to helicopter pilot candidates in 1983. In 1984, the training was revised to a two hour block and retitled Dynamics of Aircrew Coordination Training. In 1987, the Vice Chief of Staff of the Army directed the Army Research Institute (ARI) to initiate a research and development program to reduce accident rates through various means including training. ARI's subsequent research of aviation accidents showed that the majority of human error-related accidents involved crew coordination errors (Simon, 1992:1-1). In 1988, the Army Safety Center (ASC) incorporated aircrew coordination training (ACT) into its Aviation Safety Officer Course. From 1990 to 1992 the ARI, the Army Aviation Center, and the Dynamics Research Corporation coordinated their efforts to conduct aircrew coordination studies and revise aircrew training manuals. The research culminated in aircrew coordination training and evaluation materials exportable to the field. ACT was officially implemented Army-wide in 1994 (Directorate, 1998). The "central feature of the Army's crew coordination training is that it is designed to reduce the number of accidents (Simon, 1995:45).

These historical events could confound any impact RM may have had on reducing the mishap rates. The inability to quantify these major contributors to mishap prevention interferes with quantifying the effectiveness of risk management. However, there may be a correlation between the presence of RM implementation and the aviation mishap rate.

Maturation. Maturation concerns the effect time has on the subjects of the experiment. Since this research covers a relatively long period, those whose performance can affect the mishap rate may have matured over that time. This maturation may be in the form of aviation experience, training, and using safer equipment as described in Chapter II. Concerning maturation after RM implementation, it is assumed that the more Army aviators practice RM, the more likely the mishap rate would decrease. In this sense, the threat of maturation is similar to the threat of history.

Testing. If subjects are given a test, it is likely that a learning effect will occur that will influence scores of a second test on the same material. For this research, it was not possible to give a series of tests in this manner. Therefore, the testing threat to internal validity is low.

Instrumentation. Instrumentation concerns the way measurements are taken to obtain results. If changes are made in instrumentation, it is likely that the results will not be consistent. In this research, the way the mishap rate was calculated did change in 1984. This issue will be addressed in the methodology section.

Selection. The selection of subjects for control and experimental groups is important in that they need to be equivalent to minimize the threat to internal validity. In this research, the Army is the experimental group and the Air Force is the control group. It is true that their aviation components are not equivalent in every respect but, as was discussed in Chapter II, there is enough similarity concerning RM/ORM that this threat can be considered minimal.

Regression. The regression factor is in effect when groups are selected based on extremely high or low results. When tested after a treatment, the extreme

results move toward their expected value. For this research, regression analysis is performed. As a result, extreme mishap rates, outliers, are evaluated and removed as necessary. The internal threat of regression is minimal.

Experimental Mortality. This threat concerns the situation where, as an experiment continues, subjects are likely to drop out, thus affecting the results. In this study, it is assumed that attrition is not a problem because if one member of the aviation community leaves, another of similar quality will replace him. Hence, this threat to internal validity is minimal.

Interaction. The effect of interaction between any of the previous seven threats to internal validity can be confounded with the effect of a treatment, X. In this study, maturation and history have the potential to confound the impact of RM. However, since the duration of the experiment is relatively long, maturation and history could be considered one threat. The other five threats are not likely to interact. Therefore, the threat of interaction is minimal.

External Validity. External validity concerns the ability to generalize results to other populations. Both Campbell and Emory list three major threats to the external validity of an experiment where X represents the treatment (in this case, RM): 1) interaction of testing and X, 2) interaction of selection and X, and 3) reactive arrangements.

Interaction of Testing and RM. This threat can be high if a pretest occurred before X. How the subjects respond to X because of previous exposure can confound the results. In this research, it is assumed that no testing or formalized practice

of RM occurred in Army aviation before RM implementation occurred in 1987. Therefore, this threat is considered minimal to the generalizability of the research results.

Interaction of Selection and RM. This threat concerns how subjects are selected from a population for a test, or in this case the treatment of RM, and the generalizability of the results. For this research, the population of subjects is the Army aviation and safety community. The results, then, will be generalizable to the Army. However, as presented in Chapter I, the basic research question of this thesis is to determine if the Air Force can expect its mishap rate to significantly decline after ORM implementation. It is not the purpose to directly compare Army and Air Force mishap rates but to predict the effect ORM may have on the Air Force aviation mishap rate based on the effect RM may have had on the Army aviation mishap rate. It is, then, the intention to be able to generalize the results to the Air Force. This generalization can not be based on statistical results alone but in conjunction with those investigative questions addressed in Chapter II. Therefore, the threat of interaction of selection and RM is considered minimal to the generalizability of the research results.

Reactive Arrangements. This threat concerns the effect that the environment in which testing occurs may have on external validity. If testing is performed in an artificial environment separate from it original population, one may not be able to validly generalize to that population. In this research, neither the Army nor Air Force flying environments are artificial settings in which to test RM/ORM. The Army flying environment may be significantly different from that of the Air Force. However, since RM/ORM is a decision-making process applicable to any flying situation, it is assumed that those in the aviation community apply RM/ORM appropriately to their

situation. Therefore, the threat of reactive arrangement is considered minimal to the generalizability of the research results.

Summary. This section addressed the threats to both internal and external validity to the research. The major threat to its internal validity is history. Various historical events associated with aviation mishap prevention and contemporaneous with RM were presented which could confound the effect RM may have had on the mishap rate. Since the manner in which the mishap rate was calculated changed in 1984, instrumentation could also influence the effect RM may have had on the mishap rate.

Methodology, Results, and Analysis

Overview. Chapter I presented five investigative questions. The first two were answered in Chapter II. The remaining three are addressed in this chapter using statistical analysis. The questions are:

1) Was there a significant difference in the Army aircraft mishap rates after the implementation of RM? (Investigative Question 3).

2) If there was a significant difference, was the change due to the implementation of RM? (Investigative Question 3a).

3) If there was a significant difference in the mishap rate, how much of an effect was the implementation of RM? (Investigative Question 3b).

For each question, the methodology is first presented followed by the results and an analysis of the results. All statistical tests were performed using JMP® Version 3 and Mathcad® 7. The Army data analyzed is found in Appendix A and presented graphically in Figures 3 and 4. The 1991 data point was removed from the analysis because the

relatively high 1991 Class A mishap rate can be attributed to the preparation for and execution of Operation Desert Shield/Storm. Additionally, through statistical analysis, the data point was found to be an outlier for the Class A mishap rate (Appendix C).

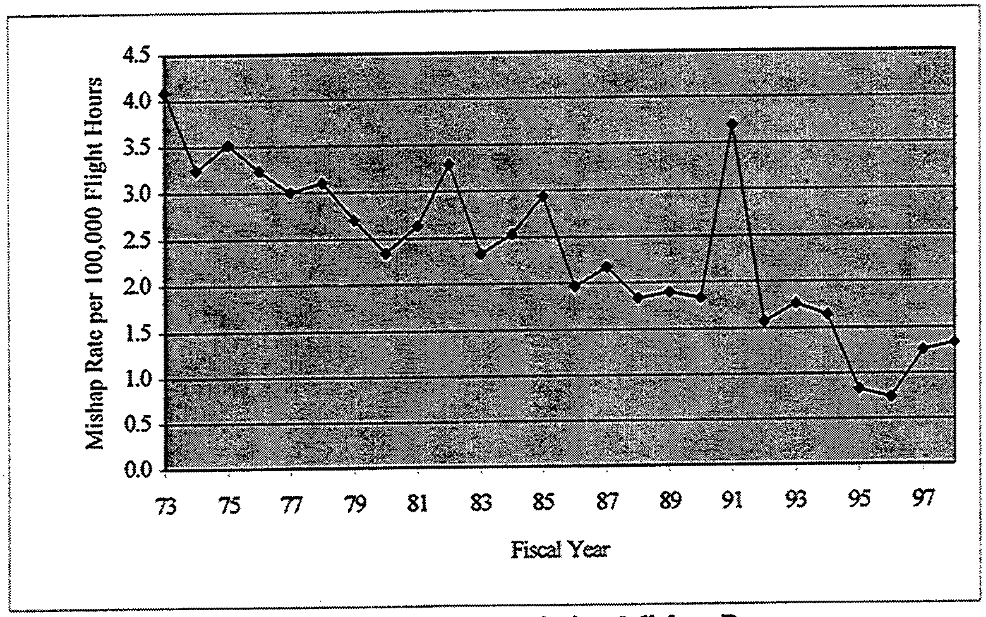


Figure 3. Army Class A Aviation Mishap Rate

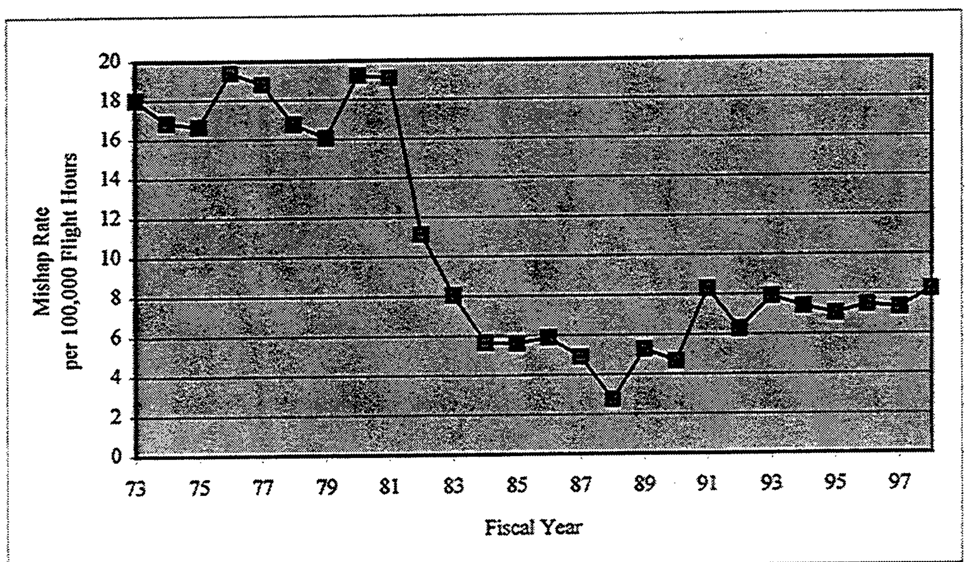


Figure 4. Army Class B-C Aviation Mishap Rate

After the 1991 data point was removed, the remaining data was shown to be from a normal distribution (Appendix D). The data point was not an outlier in the B-C category (Appendix E); however, it was removed to keep the analysis consistent.

Investigative Question 3. Was there a significant difference in the Army aircraft mishap rates after the implementation of RM? To address this question, two statistical tests were performed: 1) comparison of means test, and 2) a comparison of variances.

Comparison of Means.

Methodology. Just looking at Figures 3 and 4, one can intuitively say that the rates after 1987 are lower than those before 1987. However, to answer this question statistically, a comparison of means test for small samples was considered according to McClave (372-378). The means compared would be for the periods 1973-1987 (before RM) and 1988-1998 (after RM) for both Class A and Class B-C mishap rates. Three assumptions must be met for this test to be valid. The first assumption is that both sampled populations must have relative frequency distributions that are approximately normal. This assumption is satisfied through an analysis of the residuals (Appendix D and E). The second assumption is that the samples are randomly and independently selected from the population. To satisfy this assumption, both samples would be randomly and independently selected from the population in that all data points in the population except the outlier could be used in the analysis. The third assumption is that the population variances are equal. To attempt to satisfy this assumption, an analysis of the population variances of the values could be performed. However, this approach cannot satisfy this assumption because this research is dealing with time series data. As a result, the direct comparison of means test is not appropriate.

The problem with performing a direct comparison of means is that when time series data is analyzed, trend components must be removed before any mean analysis can be performed. If the time series is stationary, the values will "fluctuate with constant variation around a constant mean" (Bowerman, 1987:26). Since time series data is considered in this research and the mishap rate processes do not appear to be stationary, the direct comparison of means is an inappropriate test for this data. A transformation of the data to stationarity, however, does permit a comparison of means.

Since the mishap rate is expressed as a percentage (as defined in Chapter II), a way to transform the data into a form that is suitable for comparison of means is to compute the percentage period index (PPI) using the procedure described in Makridakis (1983:171). PPI is a period-to-period (in this case year-to-year) percentage change. A difference of means test comparing the mean PPI for each period is then possible. If the means are different, it indicates that a process change has occurred.

To run the test, the PPI of the first value in the data set is set equal to a constant to provide an order of magnitude. Each PPI thereafter is determined by computing the ratio of the current rate to the previous rate and multiplying the ratio by the constant. In general:

$$PPI = [(Rate_{i+1}) / (Rate_i)] \times C \qquad \text{from } i = 1 \text{ to } n \qquad (1)$$

where C = 10. The hypotheses for the test were:

Ho: the means are equal

Ha: the means are not equal

To reject the null hypothesis in the comparison of means t-test, the t-statistic must be greater than the t-critical value. The level of significance for the t-test was $\alpha = .05$.

Results. Table 3 summarizes the results of the PPI transformation that are presented in Appendix F.

Table 3. Percentage Period Index Results

Class	Year	Mean PPI	t-crit	t-stat	Reject Null?
A	1973-1987	9.73	1.714	.198	No
	1988-1998	9.92			
B-C	1973-1987	9.32	1.714	1.601	No
	1988-1998	11.02			

The results showed that there is enough evidence to suggest that the mean PPIs for both Class A and Class B-C mishap rate categories were not significantly different at the $\alpha = .05$ level of significance. Figures 5 and 6 present the PPIs graphically for both Class A and Class B-C categories respectively.

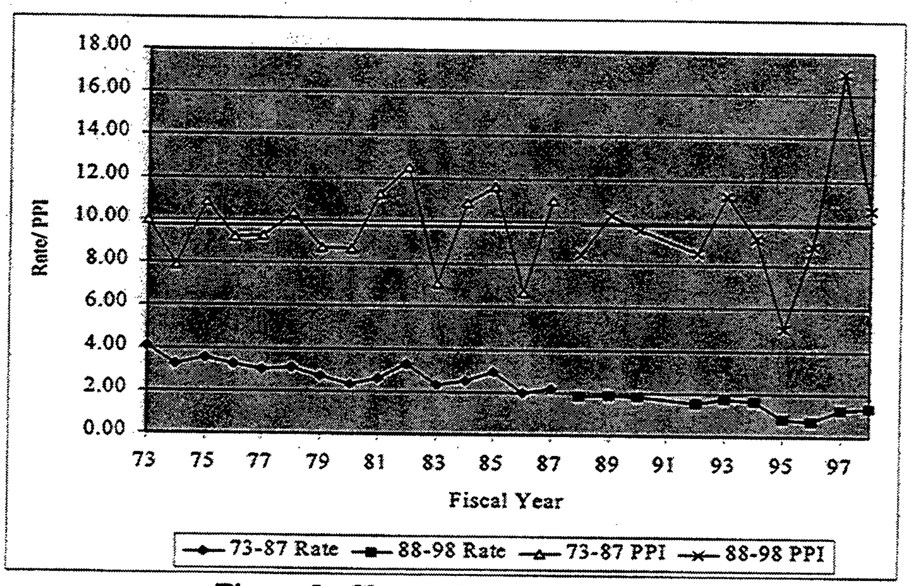


Figure 5. Class A Period Percentage Index

Analysis. Since there was no significant difference in the mean PPIs for both categories, the mean percentage change of the mishap rate from year to year can

be considered the same for both periods. This indicates that the process to reduce the mishap rate has not changed since 1987.

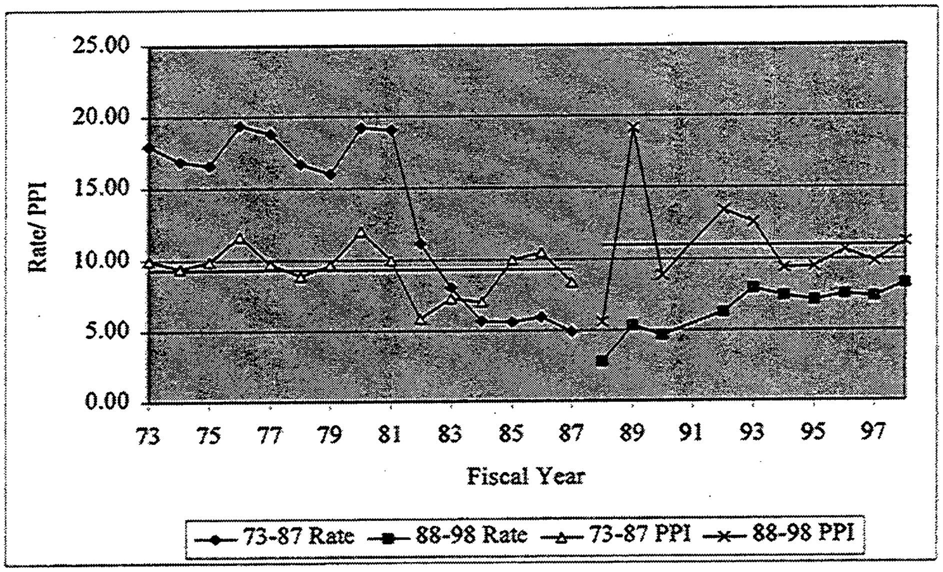


Figure 6. Class B-C Period Percentage Index

Comparison of Variances.

Methodology. As discussed earlier, it is not appropriate to compare the variances of trended data. However, it is appropriate and useful to compare the variances of the residuals of the mishap rate values regressed against the fiscal year. Since the mean of the residuals is zero, a comparison between the variances of the residuals is possible. A change in variance of the population of the residuals from one period to the next will at least determine if a process change occurred. In looking at Figures 3 and 4, it would be reasonable to expect the variance of the residuals for the Class B-C mishap rate to be different as clearly a process change has occurred around 1987. A difference in variance is not as apparent for the Class A category.

A comparison of the variances of the residuals of the mishap rate values for the time periods 1973-1987 (before RM) and 1988-1998 (after RM) for both Class A and Class B-C mishap categories was performed as described in McClave (1998:408-415). The F-statistic is computed by placing the larger variance as the numerator and the smaller as the denominator. The critical F value is determined based on the numerator and denominator degrees of freedom. If the residual variances are the same, one can conclude that there has been no process change. The hypotheses for the test were:

Ho: The residual variances are equal

Ha: The residual variances are not equal

If the F-statistic is greater than the critical F value, then the F-statistic falls in the rejection region and the null hypothesis is rejected. This concept is illustrated in Figure 7.

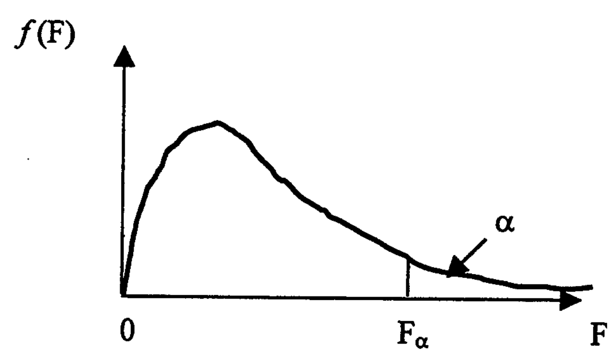


Figure 7. F-Distribution (McClave, 1998:410)

Results. The results of the comparison of variance test are presented in Appendix G and summarized in Table 4. Since the F-statistic for the Class A mishap rate did not fall in the rejection region, the null hypothesis is not rejected. The residual variances are equal. Since the F-statistic for the Class B-C mishap rate did fall

Table 4. Variance Test Results

Class	Year	Variance	F-crit	F-stat	Reject Null?
A	1973-1987	.115	3.803	1.435	No
	1988-1998	.080			
B-C	1973-1987	10.529	3.803	12.983	Yes
	1988-1998	.811			

in the rejection region, the null hypothesis is rejected. The variances are not equal.

<u>Analysis</u>. Since the residual variances for the Class A mishap rate category are equal, there is not enough evidence to conclude that a process change has occurred. However, for the Class B-C category, since the residual variances were not equal, there is enough evidence to conclude that a process change has occurred. Since RM was instituted in 1987, this is the result expected from having reviewed Figure 4.

<u>Summary</u>. Investigative question 3 asked whether there was significant difference in the mishap rate after the implementation of RM. A difference of means test was performed on the percentage period indexes for both mishap rate categories. The results showed no significant difference in the mean PPI for either category. This indicated that no process change had occurred. A comparison of the variances of the residuals of the mishap rates was then performed to confirm the absence of a process change. The results confirmed that for the Class A mishap category, no process change was evident. However, for the Class B-C mishap category, a process change was evident. A more powerful method of determining whether there was significant change in the mishap rates is to employ discontinuous piecewise linear regression. The procedure will simultaneously address whether the process change as found in the Class B-C category was due to the implementation of RM.

Investigative Question 3a. If there was a significant difference, was the change due to the implementation of RM?

Methodology. To address this question, discontinuous piecewise linear regression was performed for the periods 1973-1998. Discontinuous piecewise linear regression is used to determine if a slope and/or intercept change has occurred at a particular break point or points (Neter, 1996:474-478). A model with two variables and a break point, C, would look like this:

$$E(MR) = \beta_0 + \beta_1 {*} X_1 + \beta_2 {*} (X_1 - C) {*} X_2 + \beta_3 {*} X_2 \qquad (2)$$

where β_0 is the Y-axis intercept, β_1 is the slope of the regression line for the period before treatment C, $\beta_1 + \beta_2$ is the slope of the regression line for the period after C, and β_3 is the jump in intercept at C. Figure 8 illustrates this concept.

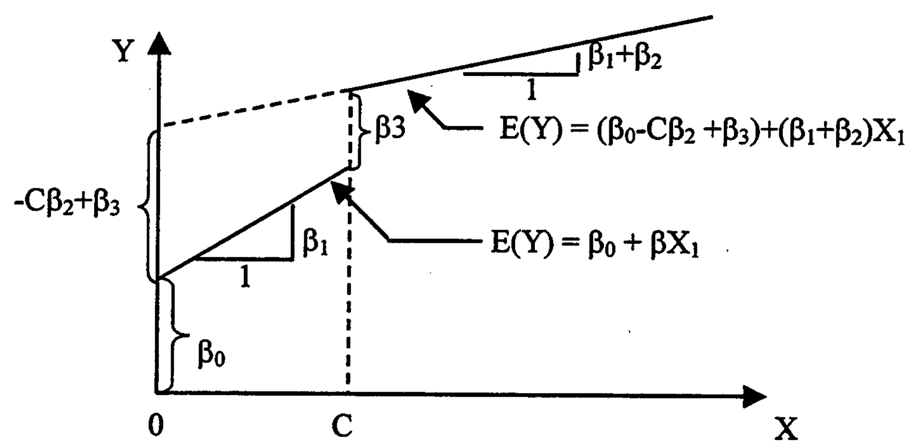


Figure 8. Discontinuous Piecewise Linear Regression Response Function (Neter, 1996:478)

If there is no significant change in the slope of the regression line at point C, then one would expect β_2 to be zero. Similarly, if there is no significant change in the intercept at C, one would expect β_3 to be zero.

Typically, with a process or policy change, one would expect to see a significant change in the data results if the policy was effective. An effective treatment would produce a shift in slope and/or intercept. A shift in intercept with no change in slope or a change in slope with no change in intercept could reveal whether the treatment caused a significant change in the process (Campbell, 1963:43).

Since Army risk management began in 1987, one might expect to see its effect evidenced by a downward shift in the intercept and/or an increased negative slope in the mishap rate regression line after 1987.

The full model consisted of two variables: FY and RM. FY is the fiscal year. RM represents the presence of risk management. From 1973-1987 RM = 0 and from 1988-1998 RM = 1. The breakpoint, C, is 87. The full model was as follows:

$$E(MR) = \beta_0 + \beta_1 * FY + \beta_2 * (FY-87) * RM + \beta_3 * RM \qquad (3)$$

where β_0 is the Y-axis intercept, β_1 is the slope of the regression line for the period 1973-1987, $\beta_1 + \beta_2$ is the slope of the regression line for the period 1988-1998, and β_3 is the jump in intercept between 1987 and 1988. As a result, three hypotheses were made for each mishap category (A, and B-C). The first hypothesis was:

$$Ho: \ \beta_1 = \beta_2 = \beta_3 = 0$$

$$Ha: \ \text{The } \beta\text{'s} \neq 0$$

The significance of the β_1 and β_3 terms can be directly determined by their p-values from the overall F-test results of the full model. However, a partial F-test must be performed on the reduced model to determine the significance of the slope of the second regression line, $\beta_1 + \beta_2$. As a result, the second hypothesis was:

$$H_o: \beta_1 + \beta_2 = 0$$

$$H_a: \beta_1 + \beta_2 \neq 0$$

Additionally, to determine if the slopes of the two regression lines are significantly different from each other, a second partial F-test must be performed. If β_2 is zero, then the slope of the second line will not be significantly different from the slope of the first line. Hence, the third hypothesis was:

$$H_o: \beta_2 = 0$$

$$H_a: \beta_2 \neq 0$$

The results and analysis of the Class A mishap category are first presented followed by those in the Class B-C mishap category. All tests were performed at an $\alpha = .05$ level of significance.

Class A Mishap Category.

Results. Tables 5 and 6 summarize the discontinuous piecewise linear regression overall and partial F-test results respectively for the Class A mishap category. With the given p-values, the overall F-test indicates that 1) the slope of the first line, β_1, is significantly different from zero and 2) that there is no significant jump at 1987. The partial F-tests on the reduced model indicate that 1) the slope of the second line, $\beta_1+\beta_2$, is significantly different from zero, and 2) the slopes of the regression

Table 5. Overall F-test Results: Class A Mishap Category

Term	Beta	Beta Coefficients	P-Value	Reject Null?
Intercept	β_0	11.016	.0001	N/A
FY	β_1	-.102	.0001	Yes
(FY-87)xRM	β_2	.011	.7672	N/A
RM	β_3	-.128	.6525	No

Table 6. Partial F-test Results: Class A Mishap Category

Beta	Slope of Line 1988-1998	F_{crit}	F_{stat}	Reject Null?
$\beta_1+\beta_2$	-.091	4.325	7.772	Yes
β_2	N/A	4.325	.09	No

lines are not significantly different from one another. Figure 9 shows the discontinuous piecewise linear regression for the Class A mishap rate. The graph suggests a continuous downward trend in the Class A mishap rate.

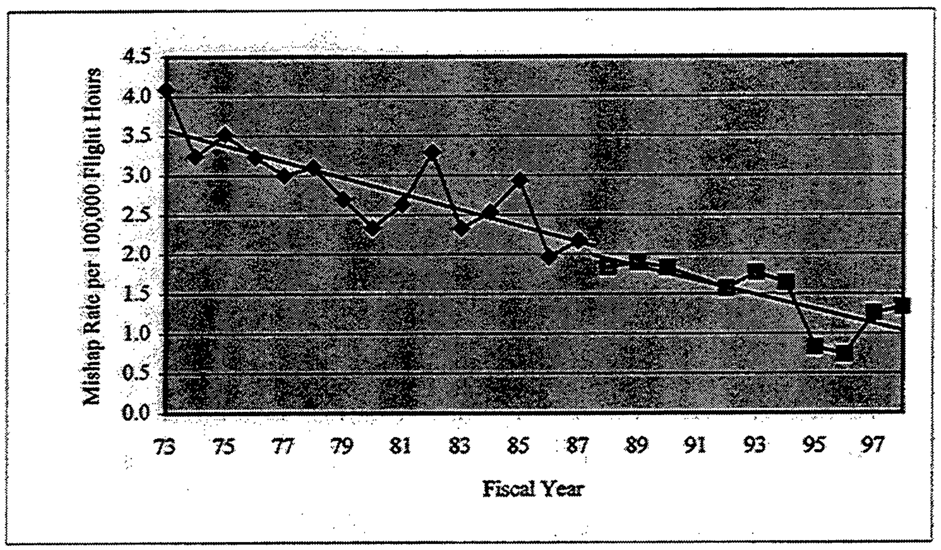


Figure 9. Class A Mishap Rate (Risk Management)

<u>Analysis</u>. Since there was no shift in the regression line at 1987 and the slopes of the two regression lines are not significantly different, there is no indication that the presence of RM has had any effect on the Class A mishap rate. These results confirm the finding of Investigative Question 3 that no process change has appeared to have occurred in the Class A mishap rate category.

Class B-C Mishap Category.

Results. Tables 7 and 8 summarize the discontinuous piecewise linear regression overall and partial F-test results respectively for the Class B-C mishap category.

Table 7. Overall F-test Results: Class B-C Mishap Category

Term	Beta	Beta Coefficients	P-Value	Reject Null?
Intercept	β_0	101.495	.0001	Yes
FY	β_1	-1.100	.0001	Yes
(FY-87)xRM	β_2	1.541	.0001	N/A
RM	β_3	-2.060	.3602	No

Table 8. Partial F-test Results: Class B-C Mishap Category

Beta	Slope of Line 1988-1998	F_{crit}	F_{stat}	Reject Null?
$\beta_1+\beta_2$	.441	4.844	1.573	No
β_2	N/A	4.325	26.497	Yes

With the given p-values, the overall F-test indicates that 1) the slope of the first line, β_1, is significantly different from zero and 2) that there is no significant jump at 1987. The partial F-tests on the reduced model indicate that 1) the slope of the second line, $\beta_1+\beta_2$, is not significantly different from zero, and 2) that the slopes of the regression lines are significantly different from one another. Figure 10 shows the discontinuous piecewise linear regression for the Class B-C mishap rate. The graph suggests an upward trend in the Class B-C mishap rate category since 1987.

Analysis. In the comparison of variances performed earlier, a process change was confirmed for the Class B-C category. If this change were due to

RM, a shift in the regression line at 1987 and/or an increased negative slope of the second regression line after 1987 would indicate that RM effected this change. However, since

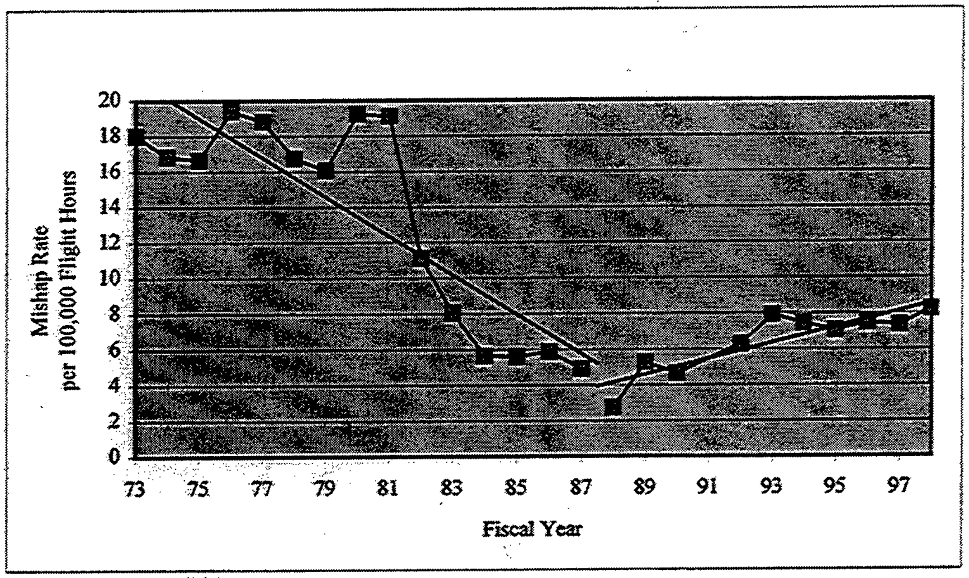


Figure 10. Class B-C Mishap Rate (Risk Management)

there was no shift and the slope of the regression line after 1987 actually reversed course and became positive, it can be said, at the least, that RM has not had its intended effect. There may be several possibilities for this. It is possible that, with the emphasis on safety that RM brings with it, a stricter reporting policy of Class B and C mishaps may have been perceived by commanders. It is also possible that the flight-related confound analyzed in the next section affected mishap reporting. In any event, the mishap cause factors discussed in Chapter II outweighed the mishap prevention factors for reasons beyond the scope of this research.

Summary. Investigative Question 3a asked whether any significant difference found in Investigative Question 3 was due to RM. Discontinuous piecewise linear regression analysis was employed to address this question. For the Class A mishap

category, the test reinforced the previous finding that no process change occurred. The conclusion is that RM has not affected the Class A mishap rate. For the Class B-C mishap category, the test confirmed a process change identified in previous analysis. In fact, since 1987, the mishap rates have increased. Several possibilities for this occurrence were discussed.

Investigative Question 3b. If there was a significant difference in the mishap rate, how much of an effect was the implementation of RM?

Although the test performed for Investigative Question 3a found a potential significant difference (change in slope) in the Class B-C mishap rate since RM implementation, it does not appear that RM has had its intended effect. This may be influenced by the confounding effect of flight-related mishaps in the rate calculation discovered during data collection. How much of an effect this confound has had on the mishap rate may change the determination of how much of an effect RM has had on the mishap rate.

Methodology. The previous analysis for the effect of RM after 1987 ignored the fact that flight-related data were included in the mishap rate calculation for the period 1973-1983. In order to test the impact of the confounding effect this may have had on the rate calculation, discontinuous piecewise linear regression analysis was performed for the period 1973-1987 for both mishap categories. The breakpoint, C, was 84. The two variables for test one were FY and FR. FR represented the presence of flight-related mishaps included in the mishap rate calculation. The full model of the expected value of the mishap rate was as follows:

$$E(MR) = \beta_0 + \beta_1{*}FY + \beta_2{*}(FY-C){*}FR + \beta_3{*}FR \qquad (4)$$

where β_0 is the Y-axis intercept, β_1 is the slope of the regression line for the first period regression line, $\beta_1 + \beta_2$ is the slope of the second period regression line, and β_3 is the jump in intercept between periods. Similar testing was performed for the period 1984-1998 (flight mishap only data) to see if there was any change from the previous RM test in the effect of RM after 1987. The breakpoint, C, was 87. The two variables for test two were FY and RM just as in the full model presented in the previous RM piecewise analysis. A summary of the variables for both tests for the Class A and Class B-C mishap categories is presented in Table 9.

Table 9. Variables for Piecewise Regression Tests

Test #	Period	FR	RM
1	1973-1983	0	N/A
	1984-1987	1	N/A
2	1984-1987	N/A	0
	1988-1998	N/A	1

The same hypotheses as in the previous analysis apply here as well. The results and analysis for the Class A category are first presented followed by those of the Class B-C category.

Class A Mishap Category.

Results: Test One. Tables 10 and 11 summarize the overall and partial F-test results respectively from test one (1973-1987) of the Class A mishap category. With the given p-values, the overall F-test indicates that 1) the slope of the first line, β_1, is significantly different from zero and 2) that there is no significant jump at 1983. The partial F-tests on the reduced model indicate that 1) the slope of the second

line, $\beta_1+\beta_2$, is not significantly different from zero, and 2) that the slopes of the regression lines are not significantly different from one another. Figure 11 presents the results graphically.

Table 10. Overall F-test Results: Class A, Test One, 1973-1987

Term	Beta	Beta Coefficients	P-Value	Reject Null?
Intercept	β_0	12.524	.0008	N/A
FY	β_1	-.122	.0051	Yes
(FY-84) x FR	β_2	-.083	.6274	N/A
FR	β_3	.479	.3519	No

Table 11. Partial F-test Results: Class A, Test One, 1973-1987

Beta	Slope of Line 1984-1987	F_{crit}	F_{stat}	Reject Null?
$\beta_1+\beta_2$	-.205	4.844	1.573	No
β_2	N/A	4.844	.249	No

Analysis: Test One. The partial F-tests showed that the slope of the regression line for the 1973-1984 period was significant, that the slope the regression line from 1984-1987 was not significant and yet the slope of the two lines were not significantly different from one another. The insignificant slope of the second regression line is most likely due to the high variability associated with having only four data points. There is not much statistical power with only four data points. However, a look at Figure 11 confirms that the slopes of the two lines are not much different. To draw conclusions from this test, more weight was put on the result that the slopes of the two lines were not significantly different. Therefore, test one indicated that there was no significant change

in the Class A mishap rate due to the inclusion of flight-related mishaps in the rate calculation.

Results: Test Two. The overall and partial F-test results respectively from test two (1984-1998) are presented in Tables 12 and 13. With the

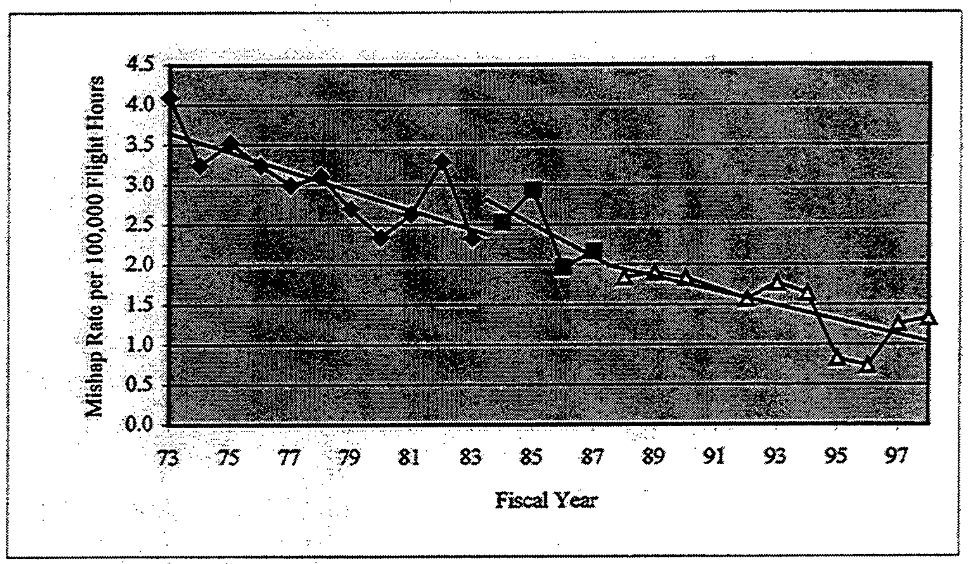


Figure 11. Class A Mishap Rate (Flight-Related Confound)

given p-values, the overall F-test indicates that 1) the slope of the first line, β_1, is not significantly different from zero and 2) that there is no significant jump at 1987.

Table 12. Overall F-test Results: Class A, Test Two, 1984-1998

Term	Beta	Beta Coefficients	P-Value	Reject Null?
Intercept	β_0	19.93	.1401	N/A
FY	β_1	-.205	.1890	No
(FY-87)xRM	β_2	.115	.4590	N/A
RM	β_3	-.063	.8618	No

Table 13. Partial F-test Results: Class A, Test Two, 1984-1998

Beta	Slope of Line 1988-1998	F_{crit}	F_{stat}	Reject Null?
$\beta_1+\beta_2$	-.09	4.965	8.158	Yes
β_2	N/A	4.965	.593	No

The partial F-tests on the reduced model indicate that 1) the slope of the second line, $\beta_1+\beta_2$, is significantly different from zero, and 2) that the slopes of the regression lines are not significantly different from one another. Figure 11 depicts the results of test two graphically.

Analysis: Test Two. Test two had similar results to test one for the 1984-1987 period. Again, the high variability of having only four data points of flight-only mishaps before the implementation of RM probably negates any relevant slope that likely exists. Conclusions drawn were based more on the results that there was no jump at 1987 and that the slopes of the two lines were not significantly different from one another. Therefore, test two validated that the flight-related mishap confound does not appear to change the fact that RM has not affected a change in the Class A mishap rate.

Class B-C Mishap Category.

Results: Test One. The results of test one (1973-1987) are summarized in Tables 14 and 15. With the given p-values, the overall F-test indicates that 1) the slope of the first line, β_1, is significantly different from zero and 2) that there is no significant jump at 1987 at the $\alpha = .05$ level of significance. The partial F-tests on the reduced model indicate that 1) the slope of the second line, $\beta_1+\beta_2$, is not significantly

Table 14. Overall F-test Results: Class B-C, Test One, 1973-1987

Term	Beta	Beta Coefficients	P-Value	Reject Null?
Intercept	β_0	64.855	.0107	N/A
FY	β_1	-.622	.0423	Yes
FR′ x FR	β_2	.435	.7442	N/A
FR	β_3	-7.277	.0839	No

Table 15. Partial F-test Results: Class B-C, Test Two, 1973-1987

Beta	Slope of Line 1984-1987	F_{crit}	F_{stat}	Reject Null?
$\beta_1+\beta_2$	-.187	4.844	.022	No
β_2	N/A	4.844	.112	No

different from zero, and 2) that the slopes of the regression lines are not significantly different from one another. Figure 12 presents the results graphically.

Analysis: Test One. Test one showed the jump at 1983 to be insignificant at $\alpha = .05$ with a p-value of the β_3 term of .0839. However, by looking at Figure 12, it is apparent that there ought to be a significant jump at 1983. Relaxing the level of significance to $\alpha = .1$ reveals that the jump is statistically significant. Practically speaking, this makes sense. Flight-related mishaps, by definition, are not usually going to result in high dollar value damage. Therefore they tend to fall into the Class B-C mishap category. By removing the Class B-C flight-related mishaps from the mishap rate calculation before 1983, one would expect a significant drop in the mishap rate. This may partially explain why the rate appears to have increased since 1987. Based on the results and practical judgement, it appears that the flight-related confound has had a significant effect on the Class B-C mishap rate. Test two determined how this change might have affected any influence that RM may have had.

Results: Test Two. The results of test two (1984-1998) are presented in Tables 16 and 17. With the given p-values, the overall F-test indicates that 1) the slope of the first line, β_1, is not significantly different from zero, and 2) that there is no significant jump at 1987. The partial F-tests on the reduced model indicate that 1) the

Table 16. Overall F-test Results: Class B-C, Test Two, 1984-1998

Term	Beta	Beta Coefficients	P-Value	Reject Null?
Intercept	β_0	21.511	.6235	N/A
FY	β_1	-.187	.7145	No
(FY-87)xRM	β_2	.576	.2822	N/A
RM	β_3	-.956	.4340	No

Table 17. Partial F-test Results: Class B-C, Test Two, 1984-1998

Beta	Slope of Line 1988-1998	F_{crit}	F_{stat}	Reject Null?
$\beta_1+\beta_2$	.389	4.844	13.41	Yes
β_2	N/A	4.844	1.279	No

slope of the second line, $\beta_1+\beta_2$, is significantly different from zero, and 2) that the slopes of the regression lines are not significantly different from one another.

Analysis: Test Two. The fact that the slope of the regression line of the 1984-1987 time period, $\beta 1$, is not significantly different from zero is not surprising because that was the same result from test one where the slope of the same line was represented by $\beta_1+\beta_2$. Based on the results, the apparent effect of the flight-related confound did not affect any influence that RM may have had.

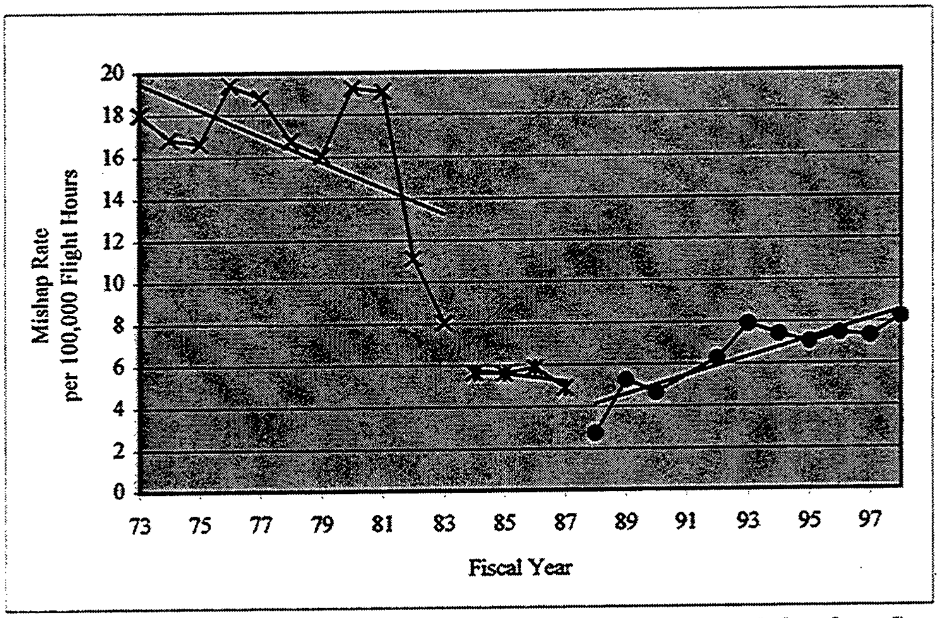


Figure 12. Class B-C Aviation Mishap Rate (Flight-Related Confound)

Summary. Given a significant difference in the mishap rate after RM implementation, Investigative Question 3a asked how much of an effect RM implementation might have had on the mishap rate. A confound discovered during data collection was that before 1983, the mishap rate calculation included flight-related mishaps. Therefore, before directly focusing the investigative question, the effect of the confound had to be addressed. To address the investigative question, then, required two steps. First, analyses of the data in the period 1973-1987 were performed with a break point at 1983. This compared mishap rates including flight-related mishaps (1973-1983) to mishap rates based on flight mishaps only but excluding the years after RM implementation (1984-1987). Second, analyses of the data in the period 1984-1998 were performed with at break point at 1987. This compared mishap rates based on flight mishaps only before and after the implementation of RM. For the Class A mishap

category, test one showed no significant change in the Class A mishap rate by excluding flight-related mishaps from the rate calculation after 1983. Test two validated that accounting for the flight-related mishap confound did not change the earlier conclusion that RM has not affected a change in the Class A mishap rate. For the Class B-C category, test one showed a significant change (at $\alpha = .1$) in the mishap rate by excluding flight-related mishaps from the rate calculation after 1983. However, this finding did not affect any influence that RM may have had on the mishap rate.

To further to address Investigative Question 3b and the flight-related confound, stepwise regression analysis was performed.

Stepwise Regression Analysis. Stepwise regression is normally used as a screening procedure to pare down a large number of independent variables to the important few for manageable model building (McClave 1998:643-648). Although only three variables were considered in the previous analyses (FY, RM, and FR), stepwise regression analysis was performed as an additional test to determine the relative importance of these variables. The variables that are selected by the stepwise process are the ones that significantly contribute to the model. The relatively less important variables will not be selected.

Inputting one variable at a time into the model performs forward stepwise regression. As each new variable is introduced, t-tests are performed to determine whether the variable belongs in the model. Backward stepwise regression is performed by inputting all variables into the model at one time and performing t-tests on each variable to determine which ones to extract from the model.

Methodology. Backward stepwise regression was conducted using JMP® Version 3 for fiscal year periods 1973-1998 and 1984-1998 for Class A and Class B-C mishap categories. To represent the effect of the mishap reporting method (flight and flight-related mishaps vs. flight mishaps only), FR = 1 for years 1973-1983 and FR = 0 for years 1984-1998. Similarly, to represent the effect of the presence of risk management, RM = 0 for years 1973-1987 and RM = 1 for years 1988-1998. The 1984-1998 data set was tested for both mishap rate categories to see if the effect of RM could be more clearly seen without the effect of the flight-related variable. Both the full and reduced mathematical models are presented in Appendix H. Coefficients of determination (R^2) values of the resulting models are also presented. The R^2 value is the percent of variability in the expected mishap rate that can be explained by using the independent variables to predict the expected mishap rate in the straight line model (McClave, 1998:467). The higher the R^2 value the more variability that is explained. The Class A mishap category results and analysis are first presented followed by those of the Class B-C mishap category.

Class A Mishaps 1973-1998.

Results and Analysis. The beta coefficients and their corresponding p-values for both the full and backward stepwise regression results are presented in Tables 18 and 19 respectively. The backward stepwise regression analysis results produced an R^2 = .8618. It also showed that the FY term was the only term that had any significant effect on the expected mishap rate. This model indicates that the expected mishap rate is on a downward trend and depends mainly upon the fiscal year.

Table 18. Stepwise Full Model: Class A, 1973-1998

Terms	Beta	Beta Coefficients	P-Values
Intercept	β_0	19.93	.1413
FY	β_1	-.205	.1929
RM	β_2	-10.0347	.4613
FR	β_3	-7.405818	.5821
FY*RM	β_{12}	.1146212	.4698
FY*FR	β_{13}	.0834545	.5972

Table 19. Stepwise Results: Class A, 1973-1998

Terms	Beta	Beta Estimates	P-Values
Intercept	β_0	11.190	.0001
FY	β_1	-.104	.0001

The results are consistent with those found in previous regression analyses. It does not appear that the inclusion of flight-related mishaps in the rate calculation was a significant factor. Nor does it appear that the presence of RM was a factor in the reduction of the Class A mishap rate.

Class A Mishaps 1984-1998.

Results and Analysis. The beta coefficients and their corresponding p-values for both the full and backward stepwise regression results are presented in Tables 20 and 21.

Table 20. Stepwise Full Model: Class A, 1984-1998

Terms	Beta	Beta Coefficients	P-Values
Intercept	β_0	19.930	.1401
FY	β_1	-.205	.1890
RM	β_2	-10.035	.4505
FY*RM	β_{12}	.115	.4590

Table 21. Stepwise Results: Class A, 1984-1998

Terms	Beta	Beta Coefficients	P-Values
Intercept	β_0	11.826	.0001
FY	β_1	-.111	.0001

The backward stepwise regression analysis results produced an $R^2 = .7474$. It also showed that the FY term was the only term that had any significant effect on the expected mishap rate. This model is virtually the same as for as the model for the 1973-1998 period. The effect of RM is no more clearly seen in this test than in the previous tests.

Class B-C Mishaps 1973-1998.

Results and Analysis. The beta coefficients and their corresponding p-values for both the full and backward stepwise regression results are presented in Tables 22 and 23. The backward stepwise regression analysis results produced an $R^2 = .8801$. It also showed that the FY*FR term was the only term that had no significant effect on the expected mishap rate. The effect of the flight-related confound

Table 22. Full Model: Class B-C, 1973-1998

Terms	Beta	Beta Coefficients	P-Values
Intercept	β_0	21.511	.8041
FY	β_1	-.187	.8537
β_1	β_2	-56.101	.5309
β_2	β_3	43.344	.6245
FY*RM	β_{12}	.627	.5472
FY*FR	β_{13}	.435	.6756

the 1973-1983 period is the same as that for the 1984-1987 period (FR = RM = 0). However, the intercepts are different. This is consistent with the earlier results that showed a significant jump in the regression line at 1983. When FR = 0 and RM = 1, the

Table 23. Stepwise Results: Class B-C, 1973-1998

Terms	Beta	Beta Coefficients	P-Values
Intercept	β_0	57.049	.0039
FY	β_1	-.602	.0079
RM	β_2	-91.639	.0025
FR	β_3	6.332	.0048
FY*RM	β_{12}	1.043	.0021

positive slope of the model indicates that during the years RM has been in effect, the Class B-C category mishap rate has increased. A discussion of the possibilities for this increase was previously presented under the piecewise regression analysis for this period.

Class B-C Mishaps 1984-1998.

Results and Analysis. The beta coefficients and their corresponding p-values for both the full model and backward stepwise regression results are presented in Tables 24 and 25.

Table 24. Full Model: Class B-C, 1984-1998

Terms	Beta	Beta Coefficients	P-Values
Intercept	β_0	21.511	.5065
FY	β_1	-.187	.6196
RM	β_2	-56.101	.1109
FY*RM	β_{12}	.627	.1241

Table 25. Stepwise Results: Class B-C, 1984-1998

Terms	Beta	Beta Coefficients	P-Values
Intercept	β_0	-29.702	.0017
FY	β_1	.412	.0005
RM	β_2	-2.245	.0204

The backward stepwise regression analysis results produced an $R^2 = .7131$. It also showed that the FY*RM term did not significantly contribute to predicting the expected

mishap rate. This model is virtually the same as the model produced in the 1973-1998 test for this period. Again, the important note of interest is the positive slope indicating an increasing Class B-C mishap trend since 1988.

Summary. Stepwise regression was employed to determine the relative significance of the variables for predicting the mishap rate. The results from all tests were consistent with those found in previous analyses. For the Class A mishap category, the rate is dependent only upon the fiscal year. For the Class B-C category the mishap rate depends not only upon the fiscal year but what policies were in effect. Prior to 1983, the flight-related confound was a significant factor. After 1987, the presence of RM was a significant variable in predicting the mishap rate. Since a purpose of RM is to prevent mishaps, it is unlikely that RM would contribute to a rising mishap rate.

Since RM is designed to prevent human error mishaps, mishap causal data was obtained for analysis of the human error-related mishaps.

Analysis of Human Error-Related Mishaps. It is estimated that 70 percent of aviation mishaps have human error as at least a causal factor (Department of Defense, 1997:31). Considering that one of the purposes of RM is to prevent human error mishaps, one might expect to see a reduction in the proportion of human error- related mishaps if RM was effective. The Army causal data before the implementation of RM was not available. Therefore, the data from 1990 to 1998 was analyzed to determine the proportion of Class A, B, and C mishaps where human error was at least a cause factor.

Results and Analysis. The results shown in Table 26 are the average proportions of causes by mishap class.

Table 26. Average Proportion of Mishaps by Cause and Class

Class	Human Error	Material Failure	Environmental	Undet.
A	.770	.251	.059	.070
B	.745	.306	.102	.082
C	.642	.225	.094	.133

Note: Proportions by class do not add to 100 percent because there can be more than one cause for a mishap

Although the number and rate of Class A mishaps has decreased in absolute terms over the years, the average proportion of human error-related Class A mishaps is comparable to the average of 70 percent cited above. The numbers and causes of Class B and C mishaps before 1990 were not available, but the average proportion since 1990 is also comparable to 70 percent. Of note is that as the average proportion of human error mishaps decreases with class, the proportion of undetermined causes increases.

Figures 13 and 14 presents the human error-related mishap proportions from 1990 to 1998. As Figure 13 shows, the trend of the proportion of human error-related mishaps is slightly increasing. Earlier analysis showed that the overall Class A mishap rate was

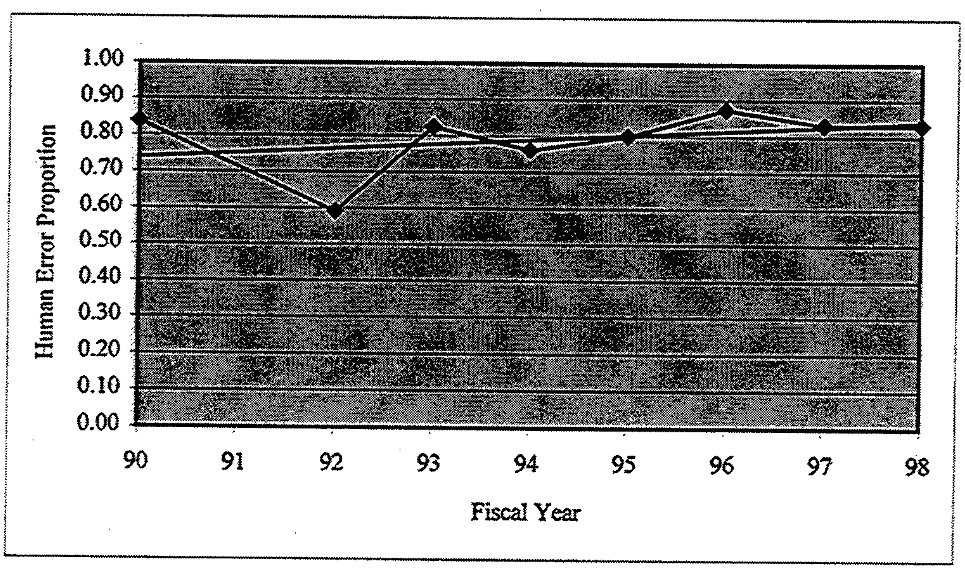


Figure 13. Class A Human Error-Related Mishap Proportions

decreasing for this period. As Figure 14 shows, Classes B and C have decreasing trends of human error-related mishap proportions. Earlier analysis showed that the overall Class B-C mishap rate was increasing during this period. Without data before 1990, it is not possible to determine any relationship between a change in the proportion of human error-related mishaps with the presence of RM. The graph indicates that the Class A mishaps related to human error are on a slight downward trend. This is consistent with previous analysis that found that the Class A mishap rate has been steadily declining since 1973. This analysis indicates that, since 1990, as the rate of human-error related mishaps declines, the overall Class A mishap rate declines. Class B mishap rate is

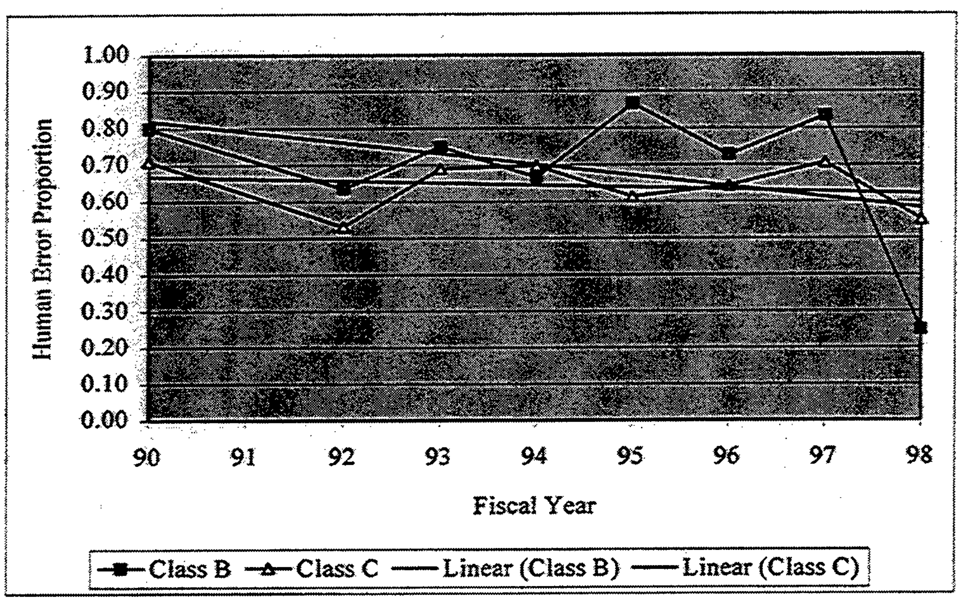


Figure 14. Classes B and C Human Error-Related Mishap Proportions

constant and the Class C mishap rate is on an upward trend. This indicates that the Class C human error-related mishap rate drives the upward

Figure 15 compares human error-related mishap rate trends for each category.

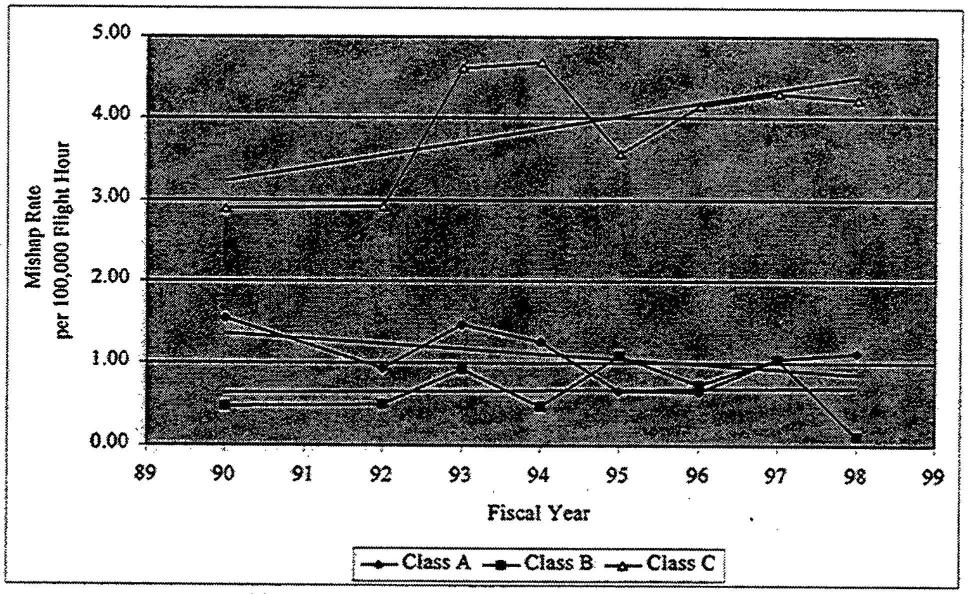


Figure 15. Human Error Mishap Rate

trend in the overall Class B-C mishap rate. Table 27 summarizes the class-human error trends for the 1990-1998 period. If RM was effective, one would expect not only

Table 27. Class - Human Error Trends

Class	Human Error Rate	Human Error Proportion
A	Decreasing	Increasing
B	Constant	Decreasing
C	Increasing	Decreasing

the human error rate to decrease but the human error proportion to decrease as well. With the data available, it is only possible to see what occurred after RM took effect.

<u>Summary</u>. This section analyzed the causal data from 1990-1998 to determine trends in the rates and proportions of human error-related mishaps. A summary of trends was presented in Table 16. If RM is to have any effect on the mishap rate, then RM should reduce the human error-related mishap rate. Additionally, the proportion of human error-related mishaps should decline. No specific conclusions concerning the

effect of RM on the human error-related causes could be drawn without causal data before 1987.

Summary

This chapter is the focal point of the research project. It addressed the sources and description of the data. It then pointed out various potential threats to the internal and external validity of the research. The largest threat to the overall validity of the research is history. Specifically, any reduction in the mishap rate must first be attributed to the mishap prevention factors described in Chapter II: leadership, mishap investigation, technological advances, and cockpit resource management. Any remaining contribution can be attributed to the impact of RM. Last, it presented the methodology, results, and analysis of the data. Four types of statistical tests were performed to analyze the data: 1) comparison of means of percentage period indexes 2) comparison of the residual variances of the mishap rate values, 3) discontinuous piecewise linear regression, and 4) stepwise regression. Finally, an analysis of the proportions and rates of human error-related mishaps by cause type was conducted.

The comparison of means test found that the mean PPIs for each time period for the Class A mishap category were not significantly different. The same was true for the Class B-C mishap category. The residual variance test found that for the Class A mishap category, there was no significant difference in the mishap rate process. However, for the Class B-C category the residual variance for the 1988-1998 time period was significantly less than that of the 1973-1987 time period. This indicated the occurrence of a process change. The piecewise linear regression analysis results indicated that the change in the

mishap rate process could not be attributed to the presence of RM. Stepwise regression analysis confirmed the piecewise analysis results. The human error-related mishap proportions analysis found was an upward trend since 1990 in the Class A category. However, for the Class B and C categories, the proportions have declined. The Class A human error-related mishap rate has declined since 1990. This is consistent with the fact that the overall Class A mishap rate has been on a downward trend since 1973. In the Class B mishap category, the rate has been constant. In the Class C mishap category, human error-related mishaps have driven the upward Class B-C mishap rates since 1990.

Based on the results, analysis, and answers to the three investigative questions addressed in this chapter, overall research conclusions and recommendations can be made. These are presented in Chapter IV.

IV. Conclusions And Recommendations

Overview

The Air Force Class A aviation mishap rate has been steadily holding at about 1.5 mishaps per 100,000 flight hours since the mid-1980's. Due to its increasingly limited resources and recent increased concern over flight safety, the Air Force is seeking ways of reducing aviation mishaps. The Army's Class A mishap rate, historically higher than that of the Air Force (Appendix B), has declined to the point where it dipped below that of the Air Force. Since the Army introduced RM in 1987, it has considered RM as a contributing factor to the Class A mishap rate reduction. The Air Force completed initial implementation of ORM in 1998 and is expecting to see its Class A mishap rate decrease. This research sought to determine what expectations the Air Force can have regarding the effect of ORM on its aviation mishap rate by examining the Army's implementation of RM and its aviation mishap data. This chapter first reviews findings based on the answers to the investigative questions. It then addresses the original research question and presents conclusions based on the overall research. Finally, it makes recommendations for future research.

Findings

Three findings are presented based on the research to answer the five investigative questions posed in Chapter I.

Finding 1. The first research question sought to determine the major factors that influence military aviation safety. Addressed in Chapter II, these factors were divided

into two types: mishap cause factors and mishap prevention factors. The mishap cause factors were based on the DoD mishap categories: human factor (error), material failure, environmental, and other. A fifth factor, though not significantly substantiated, was operations tempo. The mishap prevention factors were narrowed down to just four: leadership, mishap investigation, advancement in technology, and human error prevention programs.

Finding 2. The second investigative question sought to compare the Army's implementation of RM with the Air Force's implementation of ORM. Also addressed in Chapter II, the comparison was based on three criteria: published directives, responsibility, and training. The literature review found two minor differences in how the Army and Air Force have implemented risk management. First, there was a four year delay in the Army's integration of RM training. The Air Force implemented ORM training from the start. Second, the Army's initial focus of RM application was to the acquisition, aviation, and field training areas. The Air Force ORM implementation began in all operations and processes. Despite these differences, the Army and Air Force implementations have not been significantly different from each other.

Finding 3. Chapter III addressed the last three investigative questions using statistical analysis. The first of these asked whether there was any significant difference in the mishap rate after the implementation of RM. In absolute terms, the rates are lower, but the comparison of means of the period percentage indexes and the comparison of residual variances tests, showed that for the Class A mishap rate, there was no significant difference in the process over the years. Analysis of the Class B-C mishap rate, however, showed that there was a significant difference in the process.

Finding 3a. Since there was a difference in the Class B-C mishap category, the analysis then focused on whether this change was due to RM. Although there was no difference in the Class A mishap category, the analysis was performed to confirm the previous results. The Class A mishap rate had been on a downward trend before 1987 and, as the discontinuous piecewise linear regression analysis confirmed, there was no change in the trend after 1987. The Class B-C mishap rate had also been on a downward trend before 1987 but actually began to rise since. The analysis thus found that this change was not due to RM.

Finding 3b. The flight-related confound was not expected at the outset of this research since it was discovered during data collection. Additional analysis had to be performed to determine its effect on the mishap rate and, in turn, any effect the confound had on masking any effect RM may have had on the mishap rate. The analysis found that for the Class A mishap category, the confound had no effect on the rate. In turn, it did not affect any impact RM may have had on the mishap rate. However, for the Class B-C mishap category, the confound did have a significant effect on the mishap rate. Nevertheless, this effect did not appear to mask any impact RM had on the mishap rate. The confound may partially explain the apparent Class B-C mishap rate increase since 1987. Overall, it does not appear that RM has had much, if any effect on the Army aviation mishap rate.

Conclusions

The purpose of this research was to determine, based on the Army's experience with RM, whether the Air Force should expect a reduction in its aviation mishap rate

after the implementation of ORM. Based on the findings from the research conducted, the Air Force should not expect to see a significant decline in its mishap rate due to the implementation of ORM.

There are two possible reasons the effect of RM does not appear in the mishap rates. The first may be attributed to the findings from Chapter II. The Army began implementation of RM in 1987 but there was a delay of four years before RM was integrated into training and doctrine. Furthermore, responsibility for full integration was not formally assigned until 1997. It may be several more years before the effect of RM is reflected in its aviation mishap rates. The second reason is the effect of history. As described earlier in this chapter, many events have occurred contemporaneous with RM and since its inception that may also have affected the mishap rate. It is difficult to differentiate the effect of RM from that of aircrew coordination training (ACT) since both are aimed at reducing human error mishaps. However, the fact that ACT was not officially implemented until 1994 strengthens the argument that the effect of RM has not been reflected in the mishap rate. As a whole then, the mishap prevention factors previously described were reducing the mishap rate before and since 1987. The combination of these two reasons resulted in the undetectable effect of RM on the aviation mishap rate.

Recommendations

Based on the preceding research, two recommendations are made.

Recommendation 1. The Army should continue with the integration and application of RM throughout its operations. The groundwork has been laid in its

doctrine, education and training system, acquisitions process, and, specifically, its aviation processes. Much is yet to be done. Although the long-term mishap statistics do not appear to show it yet, an effective RM program (all else being equal) should yield a noticeable difference in the future. If the rate of human error-related mishaps declines, the Class C mishap rate should reverse course and start a downward trend.

Recommendation 2. The second recommendation is for the Air Force to learn as much about RM as it can from the Army (and other sister services). The Air Force should not expect an immediate reduction in its Class A mishap rate due to ORM. In addition, the Air Force may not see any improvements in its mishap rate at all.

Future Research

The Army and Air Force could both benefit from future research relating the effect of risk management to the aviation mishap rate.

Benefit 1. The Army data required to perform a more in-depth analysis was not available to the researcher. It would be worthwhile to look at the causal data before 1987 and compare it with the causal data after 1987. If the rates and proportions of human error mishaps declined, it may be that RM had a more significant impact than what this research showed.

Benefit 2. It may also be beneficial to repeat this analysis using a break point other than 1987. Since much of the training and integration occurred several years after initial implementation, a more appropriate break point may be defined. Results may show that after full integration of RM, and a statistically significant number of years after the new break point, the effect of RM would be reflected in the mishap rate.

Benefit 3. Since one of the Air Force leaderships' motivations for implementing ORM was to reduce the mishap rate, an analysis on the Air Force aviation mishap rate similar to that performed in this study could be useful. Similarly, since the Navy and Marines are also employing ORM, it would be useful to see what effect it has had on their aviation mishap rates.

Summary

This chapter presented the research findings, conclusions, recommendations, and future research possibilities. This research focused on the impact of RM on the Army aviation mishap rate to determine what the Air Force should expect from ORM in terms of a reduced aviation mishap rate. It concluded that the Air Force should not expect a significant reduction in its aviation mishap rate due to the implementation of ORM.

Appendix A: Army Data

		Flying	Class A		Class A-C		Class B-C		Class B		Class C	
	FY	Hours	Number	Rate	Number	Rate	Number	Rate	Number	Rate	Number	Rate
Flight and Flight Related	73	1,564,594	64	4.09	346	22.11	282	18.02	This Data Not Available			
	74	1,572,314	51	3.24	316	20.10	265	16.85				
	75	1,477,625	52	3.52	298	20.17	246	16.65				
	76	1,483,553	48	3.24	336	22.65	288	19.41				
	77	1,498,906	45	3.00	327	21.82	282	18.81				
	78	1,449,788	45	3.10	288	19.86	243	16.76				
	79	1,443,836	39	2.70	271	18.77	232	16.07				
	80	1,537,508	36	2.34	332	21.59	296	19.25				
	81	1,632,790	43	2.63	355	21.74	312	19.11				
	82	1,580,162	52	3.29	228	14.43	176	11.14				
	83	1,589,599	37	2.33	165	10.38	128	8.05				
	84	1,538,610	39	2.53	126	8.19	87	5.65				
	85	1,531,829	45	2.94	131	8.55	86	5.61				
	86	1,628,163	32	1.97	128	7.86	96	5.90				
	87	1,704,675	37	2.17	121	7.10	84	4.93				
Risk Management	88	1,741,997	32	1.84	80	4.59	48	2.76	11	0.63	37	2.12
	89	1,685,100	32	1.90	121	7.18	89	5.28	11	0.65	78	4.63
	90	1,690,601	31	1.83	110	6.51	79	4.67	10	0.59	69	4.08
	91	1,299,734	48	3.69	156	12.00	108	8.31	10	0.77	98	7.54
	92	1,400,052	22	1.57	110	7.86	88	6.29	11	0.79	77	5.50
	93	1,299,337	23	1.77	126	9.70	103	7.93	16	1.23	87	6.70
	94	1,278,098	21	1.64	116	9.08	95	7.43	9	0.70	86	6.73
	95	1,203,719	10	0.83	95	7.89	85	7.06	15	1.25	70	5.82
	96	1,082,006	8	0.74	89	8.23	81	7.49	10	0.92	71	6.56
	97	952,999	12	1.26	82	8.60	70	7.35	12	1.26	58	6.09
	98	897,870	12	1.34	86	9.58	74	8.24	6	0.67	68	7.57

Compiled from Causal Data

Appendix B: Air Force Data

Table B-1. Air Force Flight Mishap Data

		Class A		Class B		Class C	
FY	Hours	Number	Rate	Number	Rate	Number	Rate
73	4,307,058	102	2.37	42	0.98	This Data Not Available	
74	3,736,870	108	2.89	33	0.88		
75	3,359,170	93	2.77	23	0.68		
76	3,094,317	87	2.81	21	0.68		
77	3,164,334	90	2.84	299	9.45		
78	3,102,541	98	3.16	404	13.02		
79	3,189,969	94	2.95	67	2.10		
80	3,116,830	81	2.60	56	1.80		
81	3,234,307	80	2.47	54	1.67		
82	3,349,991	78	2.33	16	0.48		
83	3,404,955	59	1.73	17	0.50		
84	3,444,091	62	1.80	22	0.64		
85	3,488,910	53	1.52	25	0.72		
86	3,453,743	62	1.80	16	0.46		
87	2,648,514	40	1.51	16	0.60		
88	3,343,882	56	1.67	24	0.72		
89	3,405,758	56	1.64	5	0.15		
90	3,365,785	51	1.52	14	0.42		
91	3,684,741	41	1.11	16	0.43		
92	2,787,917	48	1.72	11	0.39		
93	2,526,079	34	1.35	15	0.59	845	33.45
94	2,256,383	35	1.55	16	0.71	723	32.04
95	2,215,443	32	1.44	19	0.86	617	27.85
96	2,167,737	27	1.25	11	0.51	550	25.37
97	2,119,769	29	1.37	16	0.75	589	27.79
98	2,111,609	24	1.14	9	0.43	497	23.54

Source: USAF Safety Center Web Site

Compiled From Causal Data

Table B-2. Average Proportion of Mishap Causes by Class, 1993-1998

Class	People	Parts	Paper	Other
A	0.637	0.122	0.139	0.101
B	0.407	0.271	0.131	0.192
C	0.276	0.389	0.058	0.277

Example: .637 = # people reasons ÷ total # reasons

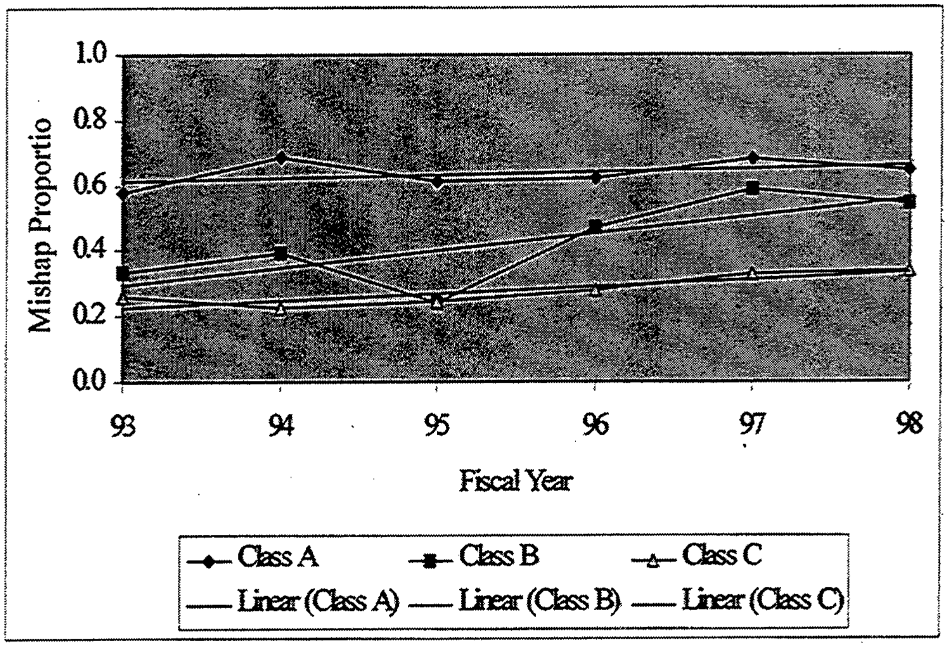


Figure B-1. USAF Mishap Reason Proportions

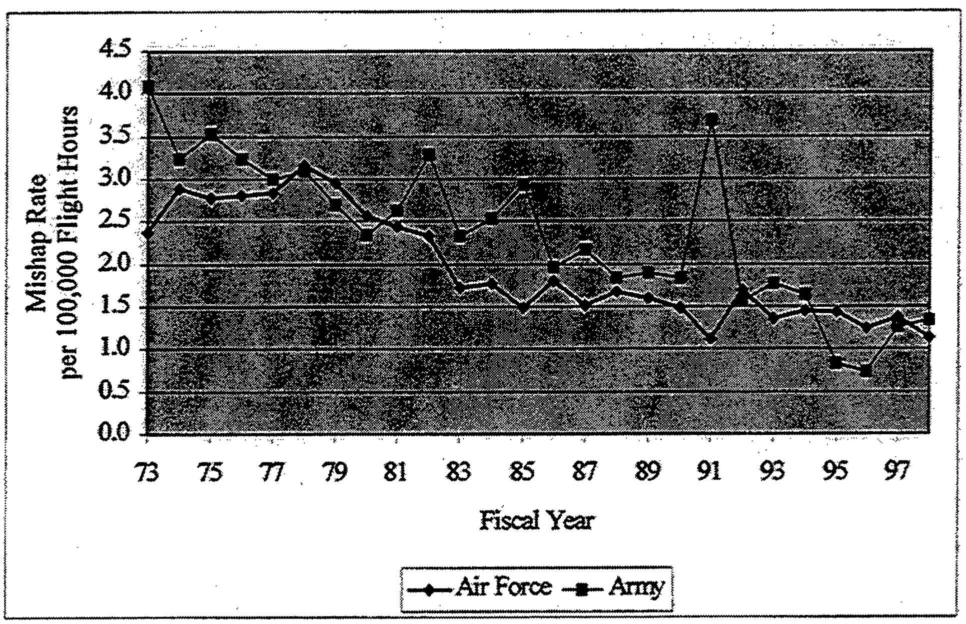
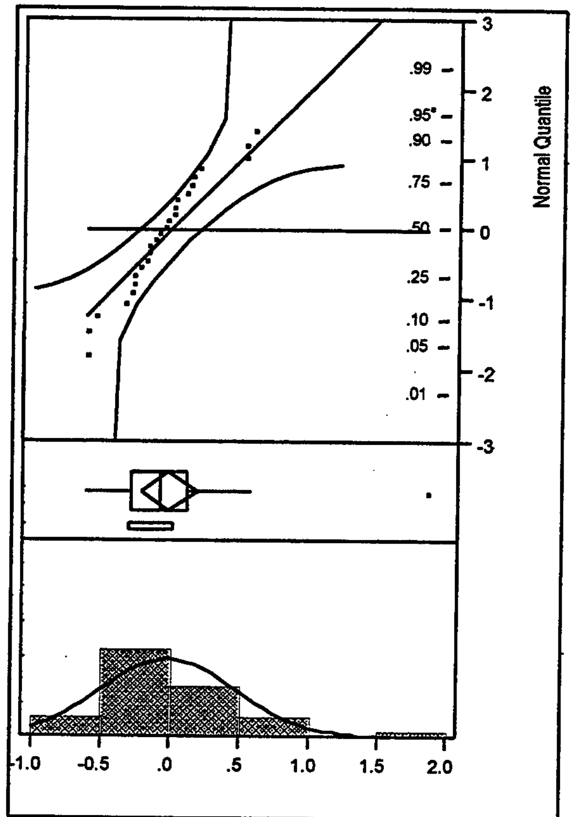


Figure B-2. Army and Air Force Class A Mishap Rates

Appendix C: Class A Relative Frequency Distribution Including 1991

Residuals Class A Rate



Moments

Mean	0.00000
Std Dev	0.49067
Std Error Mean	0.09623
Upper 95% Mean	0.19818
Lower 95% Mean	-0.19818
N	26.00000
Sum Weights	26.00000

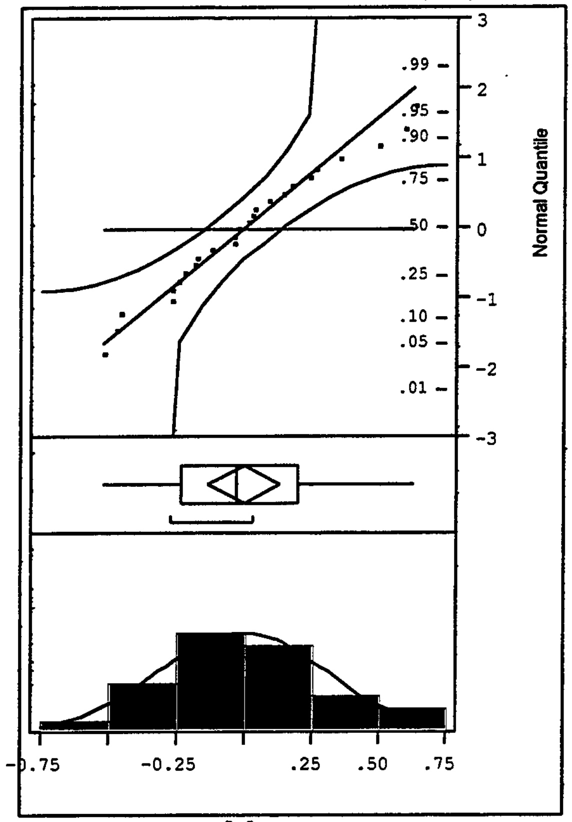
Test for Normality

Shapiro-Wilk W Test

W	Prob<W
0.803529	0.0001

Appendix D: Class A Relative Frequency Distribution Excluding 1991

Residuals Class A 73-98 (-91)



Moments

Mean	-0.00000
Std Dev	0.31333
Std Error Mean	0.06267
Upper 95% Mean	0.12933
Lower 95% Mean	-0.12933
N	25.00000
Sum Weights	25.00000

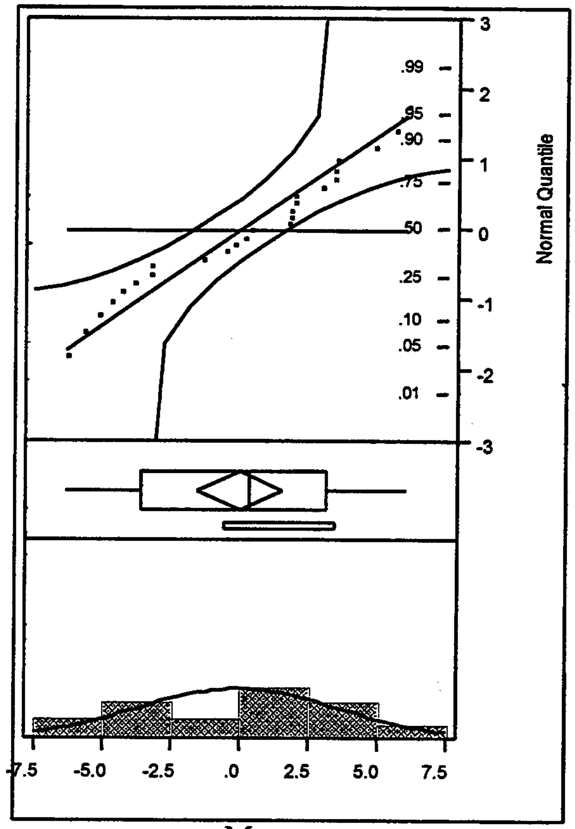
Test for Normality

Shapiro-Wilk W Test

W	Prob<W
0.966640	0.5714

Appendix E: Class B-C Relative Frequency Distribution

Residuals Class B-C Rate



Moments

Mean	0.00000
Std Dev	3.72033
Std Error Mean	0.74407
Upper 95% Mean	1.53566
Lower 95% Mean	-1.53566
N	25.00000
Sum Weights	25.00000

Test for Normality

Shapiro-Wilk W Test

W	Prob<W
0.943593	0.1882

Appendix F: Comparison of Means Percentage Period Index Test Results

Class A					Class B-C			
FY	Rate	PPI	$(x\text{-mean})^2$		FY	Rate	PPI	$(x\text{-mean})^2$
73	4.09	10.00	0.072		73	18.02	10.00	0.46
74	3.24	7.92	3.278		74	16.85	9.35	0.00
75	3.52	10.86	1.281		75	16.65	9.88	0.31
76	3.24	9.20	0.279		76	19.41	11.66	5.46
77	3.00	9.26	0.224		77	18.81	9.69	0.14
78	3.10	10.33	0.361		78	16.76	8.91	0.17
79	2.70	8.71	1.046		79	16.07	9.59	0.07
80	2.34	8.67	1.136		80	19.25	11.98	7.06
81	2.63	11.24	2.271		81	19.11	9.93	0.36
82	3.29	12.51	7.713		82	11.14	5.83	12.21
83	2.33	7.08	7.024		83	8.05	7.23	4.38
84	2.53	10.86	1.268		84	5.65	7.02	5.30
85	2.94	11.62	3.565		85	5.61	9.93	0.37
86	1.97	6.70	9.191		86	5.90	10.50	1.39
87	2.17	11.02	1.646		87	4.93	8.36	0.93
			40.354					38.61
88	1.84	8.48	2.074		88	2.76	5.59	29.44
89	1.90	10.33	0.165		89	5.28	19.17	66.42
90	1.83	9.63	0.083		90	4.67	8.85	4.71
92	1.57	8.58	1.796		92	6.29	13.45	5.92
93	1.77	11.27	1.835		93	7.93	12.61	2.54
94	1.64	9.27	0.428		94	7.43	9.38	2.69
95	0.83	5.06	23.604		95	7.06	9.50	2.30
96	0.74	8.92	1.008		96	7.49	10.60	0.17
97	1.26	17.03	50.518		97	7.35	9.81	1.45
98	1.34	10.63	0.512		98	8.24	11.22	0.04
			82.023					115.70
73-87		88-98			73-87		88-98	
mean =	9.73	mean =	9.92		mean =	9.32	mean =	11.02
variance =	2.882	variance =	9.114		variance =	2.758	variance =	12.855
	Sp^2 =	5.321	---pooled variance---			Sp^2 =	6.709	
	Diff means					Diff means		
	t-test	0.198				t-test	1.601	
	t-Crit	1.714				t-Crit	1.714	
	means are equal					means are equal		

Appendix G: Comparison of Variance Test Results

Class A		
FY	Rate	Residuals
73	4.09	0.50343
74	3.24	-0.24446
75	3.52	0.13765
76	3.24	-0.04024
77	3.00	-0.17813
78	3.10	0.02398
79	2.70	-0.27391
80	2.34	-0.53180
81	2.63	-0.13969
82	3.29	0.62242
83	2.33	-0.23547
84	2.53	0.06664
85	2.94	0.57875
86	1.97	-0.28914
87	2.17	0.09402
88	1.84	-0.14008
89	1.90	0.01582
90	1.83	0.04172
92	1.57	-0.02648
93	1.77	0.26942
94	1.64	0.23532
95	0.83	-0.47878
96	0.74	-0.47288
97	1.26	0.14301
98	1.34	0.31891

s^2_1=	0.11554
n1 =	15
df1 = n1	14
s^2_2 =	0.08049
n2 =	10
df2 = n2	9

F-stat	1.43544
F-Crit	3.803

variances are equal

Class B-C		
FY	Rate	Residuals
73	18.02	-3.03914
74	16.85	-3.1365
75	16.65	-2.26995
76	19.41	1.56692
77	18.81	2.04014
78	16.76	1.05984
79	16.07	1.43942
80	19.25	5.6954
81	19.11	6.62421
82	11.14	-0.27373
83	8.05	-2.28714
84	5.65	-3.61268
85	5.61	-2.58058
86	5.90	-1.22621
87	4.93	0.82555
88	2.76	-1.73847
89	5.28	0.39581
90	4.67	-0.60473
92	6.29	0.22415
93	7.93	1.47394
94	7.43	0.58789
95	7.06	-0.17543
96	7.49	-0.14264
97	7.35	-0.67535
98	8.24	-0.17071

s^2_1=	10.529
n1 =	15
df1 = n1	14
s^2_2 =	0.81098
n2 =	10
df2 = n2	9

F-stat	12.9831
F-Crit	3.803

variances are not equal

Appendix H: Stepwise Regression Analysis Results

The full mathematical model for the 1973-1998 time period for both Class A and Class B-C categories was:

$$E(MR) = \beta_0 + \beta_1*FY + \beta_2*RM + \beta_3*FR + \beta_{12}*FY*RM + \beta_{13}*FY*FR$$

The full mathematical model for 1984-1998 time period for both Class A and Class B-C categories was:

$$E(MR) = \beta_0 + \beta_1*FY + \beta_2*RM + \beta_3*FY*RM$$

Class A

1973-1998: $E(MR) = 11.19 - .104*FY$

1984-1998 $E(MR) = 11.826 - .111*FY$

Class B-C 1973-1998

$$E(MR) = 57.049 - .602*FY - 91.639*RM + 6.332*FR + 1.043*FY*RM$$

When FR = 1 and RM = 0 (1973-1983):

$$E(MR) = 63.381 - .602*FY$$

When FR = 0 and RM = 0 (1984-1987):

$$E(MR) = 57.049 - .602*FY$$

When FR = 0 and RM = 1 (1988-1998):

$$E(MR) = -34.59 + .441*FY$$

1984-1998 Class B-C

$$E(MR) = -29.702 + .412*FY + -2.245*RM$$

When RM = 0 (1984-1987):

$$E(MR) = -29.702 + .412*FY$$

When RM = 1 (1988-1998):

$$E(MR) = -31.94 + .412*FY$$

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Vita

Captain Park D. Ashley was born in Silver Spring, MD on 7 March 1967. He was raised in Great Falls, VA and attended Langley High School. He graduated in 1985 as a 4-year golf team letterman where he was the Number 3 player. The team won two state championships and one runner-up title, an unprecedented achievement. Captain Ashley then entered the Georgia Institute of Technology in 1985. He graduated in 1990 with a Bachelor of Mechanical Engineering degree and a commission as a 2nd Lieutenant in the United States Air Force. He came on active duty in February 1991 attending the Aircraft Maintenance/Munitions Officers Course at Chanute AFB, IL. His first assignment was to Moody AFB, GA where he was the Aerospace Ground Equipment Officer in Charge, the Fabrication Flight Commander, and the 68th Fighter Squadron maintenance officer in charge of sortie production. While in the flying squadron, he deployed to Dhahran, Saudi Arabia to support Operation Southern Watch. His second assignment was to Kunsan AB, ROK where he was the Sortie Support Flight Commander in the 35th Fighter Squadron. Captain Ashley was then assigned to Luke AFB, AZ. There he served as the 56th Logistics Support Squadron Maintenance Operations Flight Commander and the 63rd Fighter Squadron Sortie Generation Flight Commander. Captain Ashley was then selected to attend the Air Force Institute of Technology's Graduate School of Logistics and Acquisition Management to pursue a Master of Science degree in Logistics Management. His follow-on assignment is to the F-16 System Program Office. Captain Ashley is married to the former Shawn Marie Shafer of Valdosta, GA. They have two children, Celeste Marie, and Zachary Park.

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13. ABSTRACT (*Maximum 200 Words*)

The Air Force Class A aviation mishap rate has hovered around 1.5 mishaps per 100,000 flight hours since 1985. Recent attention on Air Force accidents has caused the leadership to seek to reduce its mishap rate. The Army's Class A aviation mishap rate declined after it implemented risk management (RM) principles in 1987. This reduction caught the attention of Air Force leadership who have since stated that the application of operational risk management (ORM) is how the Air Force will reduce, even eliminate, mishaps. With current budget constraints, ORM is considered to be the most cost-effective way the Air Force can reduce its mishap rate.

The purpose of this research was to determine whether the Air Force can expect its mishap rate to significantly decline due to ORM implementation. This determination is based on the relationship between the Army's implementation of RM and its aviation mishap rate. The analysis of the Army's aviation mishap rates and available causal data was performed primarily using discontinuous piecewise linear regression. Results showed that the effect of RM was not reflected in the Army's mishap rates. As a result, the Air Force should not expect its mishap rate to significantly decline due to ORM implementation.

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